Olmstead
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action not talk
is the measure of
merit —

You might as well
think of putting a
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RUDIMENTS

NATURAL PHILOSOPHY AND ASTRONOMY:

DESIGNED FOR THE

YOUNGER CLASSES IN ACADEMIES,

AND FOR

COMMON SCHOOLS.

WITH NUMEROUS ENGRAVINGS,

ILLUSTRATIVE OF PHILOSOPHICAL EXPERIMENTS.

BY DENISON OLMSTED,
PROFESSOR OF NATURAL PHILOSOPHY AND ASTRONOMY,
IN YALE COLLEGE.

NEW HAVEN.
PUBLISHED BY S. BABCOCK.
1844.

PREFACE.

Some years since, I announced to the public an intention of preparing a series of text books, in Natural Philosophy and Astronomy, adapted, respectively, to Colleges, Academies, and Common Schools. A Treatise on Natural Philosophy in two volumes, 8vo, and a Treatise on Astronomy in one volume, 8vo, a School Philosophy, and a School Astronomy, each in a duodecimo volume, have long been before the public, and have passed through numerous editions. Various engagements have prevented my completing, until now, the original plan, by adding a work of a form and price adapted to the primary schools, and in a style so easy and familiar, as to be suited to pupils of an earlier age than my previous works.

In writing a book for the pupils of our Common Schools, or for the younger classes in Academies, I do not, however, consider myself as writing for the ignorant and uncultivated, but rather for those who have but little time for these studies, and who, therefore, require a choice selection of principles, of the highest practical utility, and desire the greatest possible amount of valuable information on the subjects of Natural Philosophy and Astronomy, in the smallest compass. The image which I have had constantly before me, is that of an intelligent scholar, of [illegible] sex, from twelve to sixteen years of age, bringing to the subject a mind improved by a previous course of studies, and a capacity of being interested in this new and pleasing department of knowledge. I have imagined the learner, after having fully mastered the principles explained in the first part, which treats of Natural Philosophy, entering upon Astronomy, in the second part, with a capacity much enlarged by what he has already acquired, and with a laudable curiosity to learn the secrets of the skies. I have imagined his teacher lending him occasional aid from a map of the stars, or a celestial globe, and stimulating as well as rewarding his curiosity, by pointing out to him the constellations. It is hoped, also, that most of the teachers who use this work, will have the still higher advantage of affording to youthful curiosity a view with which it is always delighted,—that of the moon, planets, and stars, through a telescope.

I should deem myself incompetent to write a book like the present, if I had not been, myself, a teacher, first in a common school, and afterwards in an academy or grammar school of the higher order. No one, in my judgment, is qualified to write text books in any department of instruction, who does not know, by actual experience, the precise state of mind of the pupils for whom he writes. Several years of experience in teaching the rudiments of knowledge, in my early life, and the education of a large family at a later period, have taught me the devices by which the minds of young learners are to be addressed, in order that subjects at once new, and requiring some powers of reflection to understand them, may be comprehended with perfect clearness, and of course with lively pleasure. Children are naturally fond of inquiring into the causes of things. We may even go farther, and say, that they begin from infancy to interrogate nature in the only true and successful mode,—that of experiment and observation. With the taper, which first fixes the gaze of the infant eye, the child commences his observations on heat and light. With throwing from him his playthings, to the great perplexity of his nurse, he begins his experiments in Mechanics, and pursues them successively, as he advances in age, studying the laws of projectiles and of rotary motion in the arrow and the hoop, of hydrostatics in the dam and the water wheel, and pneumatics in the wind mill and the kite. I have in my possession an amusing and well executed engraving, representing a family scene, where a young urchin had cut open the bellows to find the wind. His little brother is looking over his shoulder with innocent and intense curiosity, while the angry mother stands behind with the uplifted rod, and a countenance which bespeaks the woe that impends over the young philosopher. A more judicious parent would have gently reproved the error; a more enlightened parent might have hailed the omen as indicating a Newton in disguise.

It is earnestly hoped, that the Rudiments of Natural Philosophy and Astronomy,—as much, at least, as is contained in this small volume,—will be studied in every primary school in our land. In addition to the intellectual and moral advantages, which might reasonably be expected from such a general diffusion of a knowledge of the laws of nature, and the structure of the universe, incalculable advantages would result to society from the acquaintance, which the laboring classes would thus gain, with the principles of the arts; principles which lie at the foundation of their daily operations,—for a "principle in science is a rule in art." Such a knowledge of philosophical principles, would suggest easier and more economical modes of performing the same labor; it would multiply inventions and discoveries; and it would alleviate toil by mingling with it a constant flow of the satisfaction which always attends a clear understanding of the principles of the arts.

Although this treatise is especially designed for schools, yet I would venture to recommend it to readers of a more advanced age, who may desire a concise and comprehensive view of the most important and practical principles of Natural Philosophy and Astronomy, comprising the latest discoveries in both these sciences. The part on Astronomy, especially, when compared with the sketches contained in similar works, may be found, perhaps, to have some advantages in the selection of points most important to be generally known—in perspicuity of style and arrangement—and in simplicity and fullness of illustration. It may, however, be more becoming for the author to submit this comparison to the judgment of the intelligent reader.

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RUDIMENTS

OF

NATURAL PHILOSOPHY AND ASTRONOMY.

PART I.

NATURAL PHILOSOPHY.

INTRODUCTION.*

GRAND DIVISIONS OF THE NATURAL SCIENCES.

1. As in Geography we have a clearer understanding of particular countries, if we first learn the great divisions of the globe, so we shall see more fully the peculiar nature of the sciences we are now to study, if we first learn into what distinct provinces the great empire of science is divided.

To describe and classify the *external appearances* of things in nature, is the province of Natural History; to explain the *causes* of such appearances, and of all the changes that take place in the material world, is the province of Natural Philosophy. The properties of bodies which are presented to the senses, such as form, size, color, and the like, are called *external characters;* all events or occurrences in the material world, are called *phenomena.* Natural History is occupied

*Instructors may find it expedient, in the case of very young learners, to pass over this Introduction, beginning at Chapter I; but when the state of the pupil is sufficiently advanced, we recommend its being well treasured up in the memory.

QUESTIONS.

ARTICLE 1. What is the province of *Natural History?* Of *Natural Philosophy?* What properties of bodies are called the *external characters?* What are *phenomena?* With what is Natural History chiefly

chiefly with the external characters of bodies, which it describes and classifies; Natural Philosophy, with phenomena, which it reduces under general laws. Thus, the natural historian first observes and describes the *external characters* of animals, vegetables, and minerals, and then classifies them, by arranging such as resemble each other in separate groups. The natural philosopher, also, first observes and describes the *phenomena* of nature and art, and brings together such as are similar, under separate laws; for example, the phenomena and laws of winds, of storms, of eclipses, and of earthquakes.

2. We may form some idea of the method of classification in Natural History, and of the investigation of general principles or laws in Natural Philosophy, by taking examples in each. The individual bodies that compose the animal, the vegetable, and the mineral kingdoms, are so numerous that, in a single life, we could make but little progress in acquiring a knowledge of them, if it were not in our power to collect into large groups, such as resemble each other in a greater or less number of particulars. When this is done, our progress becomes comparatively rapid; for what we then learn respecting the group, will apply equally to all the individuals comprised in it. Hence, the various bodies in the several kingdoms of nature, are distributed into classes, orders, genera, species, and varieties. Thus, those minerals which are like each other in having a certain well-known *lustre*, are collected together into one CLASS, under the head of Metals; while others destitute of this peculiar character, but having certain other characters in common, are collected into

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occupied? Ditto Natural Philosophy? Give an example of the objects of the Natural Historian. Also of the Natural Philosopher.

2. Why is it necessary to *classify* the productions of nature? How does such a classification make our progress more rapid? Into what are the various bodies in nature *distributed?*

another class, under the head of Earths.* But some metals, as lead and iron, easily rust, while others, as gold and silver, do not rust at all. Hence, metals are distributed into two ORDERS; those which easily corrode being called *base* metals, and those which do not corrode, *noble* metals. But the members of each order have severally distinctive properties, which give rise to a further division of an order into GENERA. Thus, iron constitutes one genus and lead another, of the order of base metals. But of each of these genera there are several sorts, as wrought iron and cast iron, white lead and red lead. Each genus, therefore, is subdivided into SPECIES, by grouping together such members of the same genus as resemble each other in several particulars. Finally, the individuals of each species may differ from each other, and hence the species is still further divided into VARIETIES. Thus, Swedes iron and Russia iron, are varieties of the same species of the genus wrought iron, of the order of base metals.

3. The knowledge we gain of any individual body, depends upon the extent to which we carry the classification of it. It is something to ascertain the *class* to which it belongs; for example, that the body is a metal and not an earth. It is still more to learn to what *order* of metals it belongs, as that it is one of the base and not one of the noble metals. We have advanced still further when we have ascertained that it belongs to the *genus* iron, and not to that of lead. If we find that it is wrought and not cast iron, we ascertain the species; and, finally, if we learn that it is

*This example is given merely for the purpose of illustrating the *method* of classification, and not of showing the classification of minerals as actually adopted. This would be too technical for our present purpose.

Give an example of classification in the case of *minerals*.

3. Upon what does the knowledge we acquire of any individual body depend? Show how we proceed from the *class* to the *order*, from the order to the *genus*, from the genus to the *species*, and from the species to the *variety*.

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that fell under its notice were multiplied, the field became too vast for one mind, and it was divided into two parts—what related to the earth belonged to Natural Philosophy, while the study of the heavenly bodies was erected into a separate department under the head of Astronomy. By and by, however, the whole of terrestrial nature, as the objects of inquiry were further multiplied, presented too wide a field for one mind to explore, and Natural Philosophy was restricted to the investigation of the *laws* of nature, while the description and classification of the productions of the several kingdoms of nature, was assigned to a distinct department under the name of Natural History. Still, it was a work too vast to take note of all the *phenomena* of nature and art, and investigate all the *laws* that govern them, and hence Natural Philosophy was again divided into Mechanical Philosophy and Chemistry. Mechanical Philosophy relates to the phenomena and laws of *masses* of matter; Chemistry, to the phenomena and laws of *particles* of matter. Mechanical Philosophy considers those effects only which are not attended by any change of nature, such as change of place, (or motion,) change of figure, and the like. Chemistry considers those effects which result from the action of the particles of matter on each other, and which more or less change the nature of bodies, so as to make them something different from what they were before. Finally, it became too much for one class of laborers to investigate the changes of nature or constitution, which are constantly going on in every body in nature, and in every process, natural or artificial, and Chemistry was, therefore, restricted to

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was it divided into *two parts?* What belonged to Natural Philosophy? What to Astronomy? How was Natural Philosophy still further divided? To what was it restricted? What was assigned to Natural History? Into what was Natural Philosophy again divided? To what does *Mechanical Philosophy* relate? What *Chemistry?* What *effects does* Mechanical Philosophy consider? What Chemistry?

inanimate matter, while what relates to *living* matter was erected into a separate department under the head of Physiology.

8. Natural History, moreover, found for itself an empire too vast, in attempting to describe and classify the external appearances of all things in nature. Hence this study has been successively divided into various departments, the study of vegetables being referred to Botany; of animals to Zoology; of inanimate substances to Mineralogy. Still further subdivisions have been introduced into each of these branches of Natural History, as the objects embraced in it have multiplied. Thus, the study of that branch of Zoology which relates to fishes, has been erected into a separate department under the head of Ichthyology; of birds into Ornithology; and of insects into Entomology.

9. A division of the studies which relate to the world we inhabit, has also been made into three departments, Geography, Geology, and Meteorology; all objects on the *surface* of the earth being assigned to Geography; *beneath* the surface, to Geology; and *above* the surface, to Meteorology. Of these, Geography, in this extensive signification, presents the largest field, since it comprehends, among other things, MAN and his works.

10. Mechanical Philosophy is, strictly speaking, the branch of human knowledge which we now propose to learn; but it still retains the original name, Natural Philosophy, though in a sense greatly re-

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How was Chemistry divided? To what restricted, and what was assigned to *Physiology?*

8. Into what has Natural History been successively divided? What was referred to *Botany?* What to *Zoology?* What to *Mineralogy?* What further subdivisions have been introduced into each of these branches?

9. Into what *three* departments has all terrestrial nature been divided? What is assigned to *Geography?*—what to *Geology?*—and what to *Meteorology?* *Which presents* the largest field?

stricted, compared with its ancient signification. The complete investigation of almost any subject, either of nature or art, usually, in fact, enters the peculiar province of several kindred departments of science. For example, let us follow so simple a substance as bread, from the sowing of the grain to its consumption as food, and we shall find that the successive processes involve, alternately, the principles of Mechanical Philosophy, Chemistry, and Physiology. The ploughing of the field is mechanical and not chemical, because it acts on masses of matter, and produces no change of nature in the matter on which it operates, so as to make it something different from what it was before, but merely changes its place. For similar reasons the sowing of the grain is mechanical. But now a change occurs in the nature of the seed. By the process called germination, it sprouts and grows and becomes a living plant. As this is a change which takes place between the particles of matter, and changes the nature of the body, it seems, by our definition, to belong to Chemistry, and it would do so were not the changes those of *living* matter: that brings it under the head of Physiology. All that relates to the growth and perfecting of the crop is, in like manner, physiological. The reaping, carting, and threshing the wheat, are all mechanical processes, acting as they do on masses of matter, and producing no alteration of nature, but merely a change of place. The grinding and separation of the grain into flour and bran, looks like a chemical process, because it reduces the wheat to particles, and brings out twon ew substances. We have, however, only changed the figure and place. The grain

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10. What is strictly *our* subject? What other name does it still retain? What is true of the complete investigation of any subject in nature or art? How exemplified in the case of *bread?* Why is the *ploughing* mechanical? Why is the *sowing* mechanical? Why is the *germination* physiological? How is it with the *reaping*, *carting*, and *threshing*? The *grinding* and manufacture into *flour*? Making the

coi ... of the same particles before and after grinding ... no new substance is really produced by the sep... of the flour from the bran, for both were contain... the mixture, having the same nature before as afte... separation. We next mix together flour, water, and ...st, to make bread, and bring it to the state of doug... So far the process is mechanical; but now the p... of these different substances begin to act on ea... by the process called fermentation, and new ... are produced, not existing before in eithe... ingredients, and the whole mass becomes some... a very different nature from either of the articl... ...ich it was formed. Here then is a *chemical* cl... Next we make the dough into loaves and place ... the oven by processes which are mechanic...; ...again heat produces new changes among the pa... and brings out a new substance, bread, which i... ...irely different in its nature both from the origina... ...ients and from dough. This change, therefo... ...mical. Finally, the bread is taken into the mou... masticated, and conveyed to the stomach by mech...al operations; but here it is subjected to the actio... the principle of life that governs the animal syst... and therefore again comes under the province of p...iology.

11. T... ...stinction between terms, which are apt to be co... ...ded with each other, may frequently be expresse... ...ingle words or short phrases, although they may no... ...nvey full and precise definitions. The following ar... ...amples: History respects facts; Philosophy, c... Physics, matter; Metaphysics, mind; Science, g... ...principles; Art, rules and instruments. Physical l... ... *modes* of action; moral and civil

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bread? Its ... ? Forming into *loaves* and placing in the *oven*? The b... ...*ting*?—the final change in the *stomach*?

11. What d... ...respect? What Philosophy?—Physics?—Metaphysics?— ... —*Art*? What are physical and what moral *laws*? *What* ... ...vince of Natural, and what that of Moral

laws, *rules* of action. The province of Natural Philosophy is the material world; that of Moral Philosophy is the soul. Mechanical effects result from change of place or figure; Chemical, from change of nature. Chemical changes respect inanimate matter; Physiological, living matter.

12. Mechanical Philosophy takes account of such properties of matter only as belong to all bodies whatsoever, or of such as belong to all bodies in the same state of solid, fluid, or æriform. These are few in number compared with the peculiar properties of individual bodies, and the changes of nature which they produce on each other, all of which belong to Chemistry. Chemistry, therefore, is chiefly occupied with matter; Natural Philosophy, with motion. The leading subjects of Natural Philosophy are—

1. The general properties of MATTER.
2. Motion and the Laws of Motion, constituting the doctrine of MECHANICS.
3. The Laws of Fluids in the form of water, or HYDROSTATICS.
4. The Laws of Fluids in the form of air, or PNEUMATICS.
5. The Atmosphere, or METEOROLOGY.
6. Sound, or ACOUSTICS.
7. ELECTRICITY.
8. MAGNETISM.
9. Light, or OPTICS.

Philosophy? From what do mechanical effects result?—from what chemical? What do chemical changes respect, and what physiological?

12. Of what properties does Mechanical Philosophy take account? With what is Chemistry chiefly occupied?—with what is Natural Philosophy? Enumerate the leading subjects of Natural Philosophy.

CHAPTER I.

GENERAL PROPERTIES OF MATTER.

EXTENSION AND IMPENETRABILITY—DIVISIBILITY—POROSITY—COMPRESSIBILITY—ELASTICITY—INDESTRUCTIBILITY—ATTRACTION.

13. All matter has at least two properties—Extension and Impenetrability. The smallest conceivable portion of matter occupies some portion of space, and has length, breadth, and thickness. Extension, therefore, belongs to all matter. Impenetrability is the property by which a portion of matter excludes all other matter from the space which it occupies. Thus, if we drop a bullet into water, it does not penetrate the water, it *displaces* it. The same is true of a nail driven into wood. These two properties of matter are all that are absolutely essential to its existence; yet there are various other properties which belong to matter in general, or at least to numerous classes of bodies, more or less of which are present in all bodies with which we are acquainted. Such are Divisibility, Porosity, Compressibility, Elasticity, Indestructibility, and Attraction. Matter exists in three different states, of solids, liquids, and gases. These result from its relation to heat; and the same body is found in one or the other of these states, according as more or less heat is combined with it. Thus, if we combine with a mass of ice a certain portion of heat, it passes from the solid to the liquid state, forming water; and if we add to water a certain other portion of heat, it passes into the same state as air, and becomes steam. Chemistry makes known to us a great number of bodies in

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13. What are the two *essential* properties of matter? Why does extension belong to all matter? Define impenetrability, and give an example. What other properties belong to matter? In what three different states does matter *exist?* *How* exemplified in water? What

the æriform state, called *gases*, arising from the union of heat with various kinds of matter. The particles which compose water, for example, are of two kinds, oxygen and hydrogen, each of which, when united with heat, forms a peculiar kind of air or gas.

14. *Matter is divisible into exceedingly minute parts.* A leaf of gold, which is about three inches square, weighs only about the fifth part of a grain, and is only the 282,000th part of an inch in thickness. Soap bubbles, when blown so thin as to display their gaudy colors, are not more than the 2,000,000th of an inch thick; yet every such film consists of a vast number of particles. The ultimate particles of matter, or those which admit of no further division, are called *atoms.* The atoms of which bodies are composed are inconceivably minute. The weight of an atom of lead is computed at less than the three hundred billionth part of a grain. Animalcules (insects so small as to be invisible to the naked eye, and seen only by the microscope) are sometimes so small that it would take a million of them to amount in bulk to a grain of sand; yet these bodies often have a complete organization, like that of the largest animals. They have numerous muscles, by means of which they often move with astonishing activity; they have a digestive system by which their nutriment is received and applied to every part of their bodies; and they have numerous vessels in which the animal fluids circulate. What must be the dimensions of a particle of one of these fluids!

15. *A large portion of the volume of all bodies consists of vacant spaces, or pores.* Sponge, for example, exhibits its larger pores distinctly to the naked eye.

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are bodies in the state of air called? What agent maintains matter in the state of gas?

14. *Divisibility.*—Examples in gold leaf—soap bubbles. What are atoms?—weight of an atom of lead? What are animalcules? Show the extreme minuteness of their parts.

But it also has smaller pores, of which the more solid matter of the sponge itself is composed, which are usually so small as to be but faintly discernible to the naked eye. The cells which these parts compose are separated by a thin fibre, which itself exhibits to the microscope still finer pores; so that we find in the same body several distinct systems of pores. Even the heaviest bodies, as gold, have pores, since water, when enclosed in a gold ball and subjected to strong pressure, may be forced through the sides. Most animals and vegetables consist in a great degree of matter that is exceedingly porous, leaving abundant room for the peculiar fluids of each to circulate. Thus, a thin slip or cross section of the root or small limb of a tree, exhibits to the microscope innumerable cells for the circulation of the sap.

16. *All bodies are more or less compressible, or may be reduced by pressure into a smaller space.* Bodies differ greatly in respect to this property. Some, as air or sponge, may be reduced to a very small part of their ordinary bulk, while others, as gold and most kinds of stone, yield but little to very heavy pressures. Still, columns of the hardest granite are found to undergo a perceptible compression when they are made to support enormous buildings. Water and other liquids strongly resist compression, but still they yield a little when pressed by immense forces.

17. *Many bodies, after being compressed or extended, restore themselves to their former dimensions, and hence are called elastic.* Air confined in a bladder, a sponge compressed in the hand, and india rubber drawn out, are familiar examples of elastic bodies. If we drop

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15 *Porosity.*—Example in sponge. What proof is there that gold is porous? How do we learn that animal and vegetable matter is porous?

16. *Compressibility.*—How do bodies differ in this respect? What bodies easily yield to pressure?—what yield little? How is it with granite?—with water?

on the floor a ball of yarn, or of ivory or glass, it rebounds, being more or less elastic; whereas, if we do the same with a ball of lead, it falls dead without rebounding, and is therefore non-elastic. When a body perfectly recovers its original dimensions, it is said to be *perfectly elastic*. Thus, air is perfectly elastic, because it completely recovers its former volume, as soon as the compressing force is removed, and hence resists compression with a force equal to that which presses upon it. Wood, when bent, seeks to recover itself on account of its elasticity; and hence its use in the bow and arrow, the force with which it recovers itself being suddenly imparted to the arrow through the medium of the string.

Fig. 1.

18. *Matter is wholly indestructible.* In all the changes which we see going on in bodies around us, not a particle of matter is lost; it merely changes its form; nor is there any reason to believe that there is now a particle of matter either more or less than there was at the creation of the world. When we boil water and it passes to the invisible state of steam, this, on cooling, returns again to the state of water, without the least loss; when we burn wood, the solid matter of which it is composed passes into different forms,

17. *Elasticity.*—Give examples. Show the difference between balls of ivory and lead. When is a body *perfectly* elastic? Give an example. Explain the philosophy of the bow and arrow.

18. *Indestructibility.*—Is matter ever annihilated or destroyed? What becomes of water when boiled, and of wood when burned?

some into smoke, some into different kinds of airs, or gases, some into steam, and some remains behind in the state of ashes. If we should collect all these various products, and weigh them, we should find the amount of their several weights the same as that of the body from which they were produced, so that no portion is lost. Each of the substances into which the wood was resolved, is employed in the economy of nature to construct other bodies, and may finally re-appear in its original form. In the same manner, the bodies of animals, when they die, decay and seem to perish; but the matter of which they are composed merely passes into new forms of existence, and re-appears in the structure of vegetables or other animals.

19. *All matter attracts all other matter.* This is true of all bodies in the Universe. In this extensive sense, attraction is called *Universal Gravitation.* In consequence of the attraction of the earth for bodies near it, they fall towards it, and this kind of attraction is called *Gravity.* Several distinct cases of this property occur also among the particles of matter. That which unites particles of the same kind (as those of a musket ball) in one mass, is called *Aggregation;* that which unites particles of different kinds, forming a compound, (as the particles of flour, water, and yeast in bread,) is *Affinity.* The term *Cohesion* is used to denote simply the union of the separate parts that make up a mass, without considering whether the particles themselves are simple or compound. Thus the *grains* which form a rock of sandstone, are united by cohesion. Magnetism and electricity also severally endue different portions of matter with tendencies either to attract or repel each other, which are called,

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What becomes of the bodies of animals when they die?

19. *Attraction.*—How extensive? What is it called when applied to all the bodies in the Universe? Why do bodies fall toward the earth? What *is this kind of* attraction called? What is aggregation? —*affinity?—cohesion? Give* an example of each. What are mag-

respectively, *Magnetic* and *Electric* attractions. *Tenacity*, or that force by which the particles of matter hang together, is only a form of cohesion. Of all known substances, iron wire has the greatest tenacity. A number of fine wires bound together constitute what is called a wire cable. These cables are of such prodigious strength that immense bridges are sometimes

Fig. 2.

suspended by them. The Menai bridge, in Wales, one of the greatest works in modern times, is thus supported at a great height, although it weighs towards two thousand tons.

CHAPTER II.

MECHANICS.

MOTION IN GENERAL—LAWS OF MOTION—CENTRE OF GRAVITY—PRINCIPLES OF MACHINERY.

20. Mechanics, or the Doctrine of Motion, *is that part of Natural Philosophy which treats of the laws of equilibrium and motion.* It considers also the nature of the *forces* which put bodies in motion, or which maintain them either in motion, or in a state of rest or equilibrium. The great principles of motion are the

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netic and electric attractions? Define tenacity. What substance *has the greatest?* How employed in bridges?

20. Define Mechanics. What are those agents called which put same every where, being applicable alike to solids, liquids and gases; to the most common objects around us, and to the heavenly bodies. The science of Mechanics, therefore, comprehends all that relates to the laws of motion; to the forces by which motion is produced and maintained; to the principles and construction of all machines; and to the revolutions of the heavenly bodies.

Section 1.—*Of Motion in general.*

21. Motion is change of place from one point of space to another. It is distinguished into real and apparent; absolute and relative; uniform and variable. In *real* motion, the moving body itself actually changes place; in *apparent* motion, it is the spectator that changes place, but being unconscious of his own motion, he refers it to objects without him. Thus, when we are riding rapidly by a row of trees, these seem to move in the opposite direction; the shore appears to recede from the sailor as he rapidly puts to sea; and the heavenly bodies have an apparent daily motion westward, in consequence of the spectator's turning with the earth on its axis to the east. *Absolute* motion is a change of place from one point of space to another without reference to any other body: *Relative* motion is a change of position with respect to some other body. Two bodies may both be in absolute motion, but if they do not change their position with respect to each other, they will have no relative motion, or will be relatively at rest. The men on board a ship under sail, have all the same absolute motion,

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bodies in motion or keep them at rest? How extensively do the great principles of motion prevail? What does the science of mechanics comprehend?

21. Define motion. Into what varieties is it distinguished? Explain the difference between real and apparent motion. Give examples of apparent motion. Distinguish between absolute and relative motion. Example *in the case of* persons on board a ship—in the case

and so long as they are still, they have no other; but whatever changes of place occur among themselves, give rise to relative motions. If two persons are travelling the same way, at the same rate, whether in company or not, they have no relative motion; if one goes faster than the other, the latter has a relative motion backward equal to the difference of their rates; and if they are travelling in opposite directions, their relative motion is equal to the sum of both their motions. A body moves with a *uniform* motion when it passes over equal spaces in equal times; with a *variable* motion, when it passes over unequal spaces in equal times. If a man walks over just as many feet of ground the second minute as the first, and the third as the second, his motion is uniform; but if he shonld walk thirty feet one minute, forty the next, and fifty the next, his motion would be variable.

22. *Force is any thing that moves, or tends to move a body.* The strength of an animal exerted to draw a carriage, the impulse of a waterfall in turning a wheel, and the power of steam in moving a steamboat, are severally examples of a force. A weight on one arm of a pair of steelyards, in equilibrium with a piece of merchandise, although it does not move, but only *tends* to move the body, is still a force, since it would produce motion were it not counteracted by an equal force. The quantity of motion in a body is called its *momentum.* Two bodies of equal weight, as two cannon-balls, will evidently have twice as much motion as one; nor would it make any difference if they were united in one mass, so as to form a single body of twice the weight of the separate balls; the quantity of motion would be doubled by doubling the mass, while the velocity remained the same. Again, a ball that

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of travellers? When does a body move with *uniform* motion? When with *variable* motion? Example.

22. *Define force.* Examples. What is momentum? Upon what

moves twice as fast as before, has twice the quantity of motion. Momentum therefore depends upon two things—the velocity and quantity of matter. A large body, as a ship, may have great momentum with a slow motion; a small body, as a cannon-ball, may have great momentum with a swift motion; but where great quantity of matter (or *mass*) is united with great swiftness, the momentum is greatest of all. Thus, a train of cars on a railroad moves with prodigious momentum; but the planets in their revolution around the sun, with a momentum inconceivably greater.

23. To the eye of contemplation, the world presents a scene of boundless *activity*. On the surface of the earth, hardly any thing is quiescent. Every tree is waving, and every leaf trembling; the rivers are running to the sea, and the ocean itself is in a state of ceaseless agitation. The innumerable tribes of animals are in almost constant motion, from the minutest insect to the largest quadruped. Amid the particles of matter, motions are unceasingly going forward, in astonishing variety, that are effecting all the chemical and physiological changes to which matter is constantly subjected. And if we contemplate the same subject on a larger scale, we see the earth itself, and all that it contains, turning with a steady and never ceasing motion around its own axis, wheeling also at a vastly swifter rate around the sun, and possibly accompanying the sun himself in a still grander circuit around some distant center. Hence, almost all the phenomena or effects which Natural Philosophy has to investigate and explain are connected with motion and dependent on it.

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two things does it depend? What union of circumstances produces great momentum? Example.

23. What proofs of activity do we see in nature? Give examples in the vegetable kingdom—in the animal—among the particles of matter—and among the heavenly bodies. Upon what are almost all the phenomena of *Natural Philosophy* dependent?

Sec. 2.—*Of the Laws of Motion.*

24. Nearly all the varieties of motion that fall within the province of Mechanical Philosophy, have been reduced to three great principles, called the Laws of Motion. We will consider them separately.

First Law.—*Every body will persevere in a state of rest, or of uniform motion in a straight line, until compelled by some force to change its state.* This law contains four separate propositions; first, that, unless put in motion by some external force, a body always remains at rest; secondly, that when once in motion it always continues so unless stopped by some force; thirdly, that this motion is uniform; and fourthly, that it is in a straight line. Thus, if I place a ball on a smooth sheet of ice, it will remain constantly at rest until some external force is applied, having no power to move itself. I now apply such force and roll it; being set in motion, it would move on forever were there no impediments in the way. It will move uniformly, passing over equal spaces in equal times, and it will move directly forward in a straight course, turning neither to the right hand nor to the left. This property of matter to remain at rest unless something moves it, and to continue in motion unless something stops it, is called *Inertia*. Thus the inertia of a steamboat opposes great resistance to its getting fully into motion; but having once acquired its velocity, it continues by its inertia to move onward after the engine is stopped, until the resistance of the water and other impediments destroy its motion. The planets continue to revolve around the sun for no other reason than this, that they were put in motion and meet with nothing to stop them. Whenever a horse harnessed to a carriage starts suddenly forward, he breaks his traces

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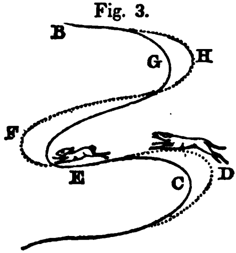
24. To how many great principles have all the varieties of motion been reduced? What are they called? State the first law. Enumerate the four propositions contained in this law. Example. Wha

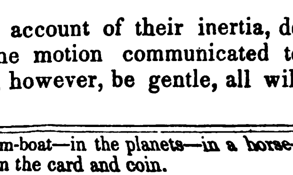
because the inertia of the carriage prevents the sudden motion being instantly propagated through its mass, and the force of the horse being all expended on the traces, breaks them. On the other hand, if a horse suddenly stops, when on a run, the rider is thrown over his head; for having acquired the full motion of the horse, he does not instantly lose it, but, on account of his inertia, continues to move forward after the force that put him in motion is withdrawn. This principle is pleasingly illustrated in what is called the *doubling* of the hare. A hare closely pursued by a greyhound, starts from A and when he arrives at C, the dog is hard upon him; but the hare being a lighter animal than the dog, and having of course less inertia, turns short at C and again at E, while the dog cannot stop so suddenly, but goes farther round at D and also F, and thus the hare outruns him.

Fig. 3.



Put a card of paste board across a couple of wine glasses, and two sixpences directly over the glasses, as in the figure; then strike the edge of the card at A a smart blow, and the card will slip off and leave the money in the glasses. The coins, on account of their inertia, do not instantly receive the motion communicated to the card. If the blow, however, be gentle, all will go off together.

Fig. 4.



is inertia? Example in a steam-boat—in the planets—in a horse—in the *doubling of a hare*—and in the card and coin.

25. The first law of motion also asserts, that moving bodies have a tendency to move in *straig lines.* We see, indeed, but few examples of sü motions either in nature or art. If we throw a b upwards, it rises and falls in a curve; water spouti into the air does the same; rivers usually run a trees wave in curves; and the heavenly bodies ı volve in apparent circles. Still, when we attentive examine each of these cases, and every other case motion in curves, we find one or more forces ope: ting to cause the body to deviate from straight line. When such cause of (viation is removed, the body imme ately resumes its progress in a straig line. This effort of bodies, when m(ing in curves, to proceed directly f(wards in a straight line, is called t *Centrifugal Force.* If we turn a grir stone, the lower part of which dips in water, as the velocity increases t water is thrown off from the rim straight lines which touch the rim a are therefore called *tangents** to it; a it is a general principle, that when bodi free to move, revolve in curves abou centre, they have a constant tendency fly off in straight lines, which are ta gents to the curves. We see this prin ple exemplified in giving a rotary n tion to a pail or bason of water. T liquid first rises on the sides of the vessel, and if t rapidity of revolution be increased, it escapes fr(

Fig. 5.

*A line is said to be a tangent to a curve, when it touches the cu but does not cut it.

25. Are the motions observed in the natural world, usually p *formed* in straight or in curved lines? Why then is it said that bo(*naturally* move in straight lines? What is this effort to move

the top in straight lines which are tangents to the rim of the vessel. If we pass a cord through a staple in the ceiling of a room, and bringing down the two ends, attach them to the ears of a pail containing a little water, (suspending the vessel a few feet above the floor,) and then, applying the palms of the hands to the opposite sides of the pail, give it a steady rotary motion, the water will first rise on the sides of the vessel and finally be projected from the rim in tangents. The experiment is more striking if we suffer the cord to untwist itself freely, after having been twisted in the preceding process.

26. SECOND LAW. *Motion, or change of motion, is proportioned to the force impressed, and is produced in the line of direction in which that force acts.* First, the quantity of motion, or momentum, is proportioned to the force applied. A double blow produces a double velocity upon a given mass, or the same velocity upon twice the mass. Two horses applied with equal advantage to a load, will draw twice the load of one horse. It follows also from this law, that every force applied to a body, however small that force may be, produces *some* motion. A stone falling on the earth moves it. This may seem incredible; but if we suppose the earth divided into exceedingly small parts, each weighing only a pound for example, then we may readily conceive how the falling stone would put it in motion. Now the effect is not lost by being expended on the whole earth at once; the momentum produced is the same in both cases; but in proportion as the quantity of matter is increased the velocity is diminished, and it would be as much less

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straight lines called? Example in a grindstone—in a suspended vessel of water.

26. What is the second law of motion? Show that the quantity of motion is proportioned to the force applied. Explain how the smallest force produces *some* motion.

as the weight of the whole earth exceeds one pound. It would therefore be inappreciable to the senses, but still capable of being expressed by a fraction, and therefore a real quantity. "A continual dropping wears away stone." Each drop, therefore, must contribute something to the effect, although too small to be perceived by itself.

27. Secondly, motion is produced in the line of *direction* in which the force is applied. If I lay a ball on the table and snap it with my thumb and finger, it moves in different directions according as I change the direction of the impulse; and this is conformable to all experience. A single force moves a body in its own direction, but two forces acting on a body at the same time, move it in a line that is intermediate between the two. Thus, if I place a small ball, as a marble, on the table, and at the same moment snap it with the thumb and finger of each hand, it will not move in the direction of either impulse but in a line between the two. A more precise consideration of this case has led to the following important law:

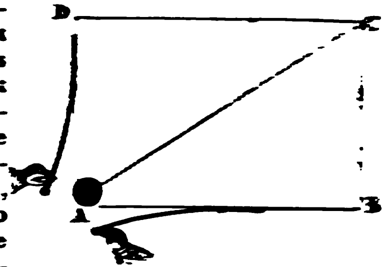
If a body is impelled by two forces which may be represented in quantity and direction by the two sides of a parallelogram, it will describe the diagonal in the same time in which it would have described each of the sides separately, by the force acting parallel to that side.

Thus, suppose the parallelogram A B C D, represents a table, of which the side A B is just twice the length of A D. I now place the ball on the corner A, and nail a steel spring (like a piece of watch spring) to each side of the corner, so that when bent back it may be sprung upon the ball, and move it parallel to the edge of the table. I first spring each force separately, bending back that which acts parallel to the

27. Show that motion is in the line of direction of the force. How does a single force move a body? How do two forces move it? Recite the law represented in figure 6, and explain the figure.

ıger side so much farther from the other, that the ll will move over the two sides in precisely the me time, suppose two seconds. I now let the springs the ball at the same instant, and the ll moves across the table, from corner to corner, in the me two seconds.

Fig. 1.



ds. It is not necessary that the parallelogram ould be right angled like a table. The effect will the same at whatever angle the sides of the parallelogram meet.

28. If I take a triangular board instead of the table, d fix three springs at one corner, so as to act parallel to the three sides of the board, and give each ring a degree of strength proportioned to the length the side in the direction of which it acts, and then t all those springs fall upon the ball at the same instant, the ball will remain at rest. This fact is expressed in the following proposition:

If three forces, represented in quantity and direction the three sides of a triangle, act upon a body at the me time, it will be kept at rest.

A kite is seen to rest in the air on this principle, ing in equilibrium between the force of gravity hich would carry it towards the earth, that of the ring, and that of the wind, which severally act in e three directions of the sides of a triangle, and

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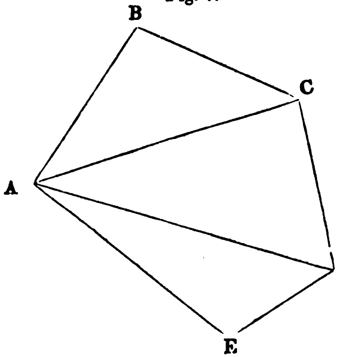
28. What is the effect of three forces, represented in quantity and direction by the three sides of a triangle? How does a kite exemplify this principle? Is the principle confined to three directions?

neutralize each other. Nor is the principle confine to *three* directions merely, but holds good for a poly gon of any number of sides. For example, a bod situated at A, and acted upon by five forces repre sented in quantit and direction b the five sides o the polygon (Fig 7,) would remai at rest. If the for ces were only fou corresponding t all the sides of th figure except th last, EA, then th body would de scribe this side i the same time i which it would de scribe each of the sides by the forces acting sepa rately.

Fig. 7.



29. *Simple* motion is that produced by one force *compound* motion, that produced by the joint action o several forces. Strictly speaking, we never witnes an example of simple motion; for when a ball i struck by a single impulse, although the motion i simple relatively to surrounding bodies, yet the ba is at the same time revolving with the earth on i axis and around the sun, and subject perhaps to inn merable other motions. Although all bodies on th earth are acted on at the same moment by many fo ces, and therefore it is difficult or even impossible tell what is the line each describes in space und

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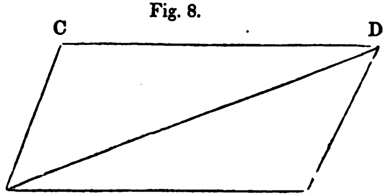
Case of a polygon of five sides? Where only four forces are a plied, how will the body move?

29. What is simple, and what compound motion? Do we ev witness simple motions in nature? Example. When a force

their joint action, yet each individual force produces precisely the same change of direction in the body as though it were to act alone. If it acts in the same direction in which the body is moving, it will add its own amount; if in the opposite direction, it will subtract it; if sideways, it will turn the body just as far to the right or left in a given time, as it would have done had it been applied to the body at rest. Thus, if while a body is moving from A to B, (Fig. 8,) it be struck by a force in the direction of AC, it will reach the line CD, in the same time in which it would have done had it been subject to no other force. It will, however, reach that line in the point D instead of C. When a man walks the deck of a ship under sail, his motions are precisely the same with respect to the other objects on board, as though the ship were at rest; but the line which he actually describes under the two forces is very different.

Fig. 8.



30. Instances of this diagonal motion are constantly presented to our notice. In crossing a river, the boat moves under the united impulses of the oars and the current, and describes the diagonal whose sides are proportional to the two forces respectively. Equestrians sometimes exhibit feats of horsemanship by leaping upwards from the horse while running, and recovering their position again. They have, in fact,

applied to a body in motion, what is the effect? Explain from Fig. 8. Case of a man walking the deck of a ship.

30. Examples of diagonal motion. A boat crossing a river—Equestrians—*Two men in a boat tossing* a ball—Rowing.

only to rise and fall as they would do were the horse at rest; for the forward motion which the rider retains by his inertia, during the short interval of his ascent and descent, carries him onward, so that he rises in one diagonal and falls in another. Two men sitting on opposite sides of a boat in rapid motion, will toss a ball to each other in the same manner as though the boat were at rest; but the actual movement of the ball will be diagonal. Rowing, itself, exemplifies the same principle; for while one oar would turn the boat to the left and the other to the right, it actually moves ahead in the diagonal between the two directions.

31. When, of two motions impressed upon a body, one is the uniform motion which results from an impulse, and the other is produced by a force which acts continually, the path described is a curve. Thus, when we shoot an arrow into the air, the impulse given by the string tends to carry it forward uniformly in a straight line; but gravity draws it continually away from that line, and makes it describe a curve. In the same manner the planets are continually drawn away from the straight lines in which they tend to move, by the attraction of the sun, and are made to describe curved orbits about that body.

32. THIRD LAW. *When bodies act on each other, action and reaction are equal, and in opposite directions.* The meaning of this law is, that when a body imparts a motion in any direction, it loses an equal quantity of its own—that no body loses motion except by imparting an equal amount to other bodies—that when a body receives a blow it gives to the striking body an equal blow—that when one body presses on another it receives from it an equal pressure—that when one body

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31. Under what two forces will a body describe a curve? Examples—An arrow—The planets.

32. Give the third law of motion. Explain its meaning. Exam-

attracts or repels another, it is equally attracted or repelled by the other. If a steam-boat should run upon a sloop sailing in the same direction with a slower motion, it might drive it headlong without experiencing any great shock itself; still its own loss of motion would be just equal to that which it imparted to the sloop, but being distributed over a quantity of matter so much greater, the loss might be scarcely perceptible. If a light body, as the wad of a cannon, were fired into the air, it would be stopped by the resistance of the air; but its own motion would be lost only as it imparted the same amount to the air, and thus might be sufficient, on account of the lightness of air, to set a large volume in motion. When the boxer strikes his adversary, he receives an equal blow from the reaction of the part struck; but receiving it on a part of less sensibility, he is less injured by it than his adversary by the blow inflicted on him. One who falls from an eminence on a bed of down, receives in return a resistance equal to the force of the fall, as truly as one who falls on a solid rock; but, on account of the elasticity of the bed, the resistance is received gradually, and is therefore distributed more uniformly over the system. A boatman presses against the shore, the reaction of which sends the boat in the opposite direction. He strikes the water with his oar backwards, and the boat moves forwards. The fish beats the water with his tail, first on one side and then on the other, and moves forward in the diagonal between the two reactions. The bird beats the air with her wings, and the resistance carries her forward in the opposite direction. All attractions likewise are mutual. The iron attracts the magnet just as much as the magnet attracts the iron. The earth attracts the sun just as much as the sun attracts the earth. In all these cases the

ples of a steam-boat running upon a sloop—a wad fired into the air—a boxer—falling *upon a feather bed*—a boatman—a bird—[illegible].

mentum or quantity of motion in the smaller and the larger body, is the same. Thus, when a small boat is drawn by a rope towards a large ship, the ship moves towards the boat as well as the boat towards the ship, and with the same momentum ; but the space over which the ship moves is as much less than that of the boat, as its quantity of matter is greater. It makes no difference whether the boat is drawn towards the ship by a man standing in the boat and pulling at a rope fastened to the ship, or by a man standing in the ship and pulling by a rope fastened to the boat. A fisherman once fancied he could manufacture a breeze for himself by mounting a pair of huge bellows in the stern of his boat, and directing the blast upon the sail. But he was surprised to find that it had no effect on the motion of the boat. We see that the reaction of the blast would tend to carry the boat backwards just as much as its direct action tended to carry the boat forwards.

Fig. 9.

33. Falling bodies. When a body falls freely towards the earth from some point above it, it falls continually faster and faster the longer it is in falling. Its motion therefore is said to be *uniformly accelerated*. All bodies, moreover, light and heavy, would fall equally fast were it not for the resistance of the air which buoys up the lighter body more than it does the

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Compare the momentum of a small boat with that of a large ship when drawn together. Case of a man who put a pair of bellows to his boat

33. When is the motion of a body said to be uniformly accelerated heavier; but in a space free from air, or a vacuum, a feather falls just as fast as a guinea. If a boy knocks a ball with a bat on smooth ice, it will move on uniformly by the impulse it has received; but if several other boys strike it successively the same way, its velocity is continually increased. Now gravity is a force which acts incessantly on falling bodies, and therefore constantly increases their speed. If I ascend a high tower and let a ball fall from my hand to the ground, it will fall $16\frac{1}{12}$ feet in one second, $64\frac{1}{3}$ in two seconds, and $257\frac{1}{3}$ in four seconds; that is, a body will fall four times as far in two seconds as in one, and sixteen times as far in four seconds as in one. Now four is the square of two, and sixteen is the square of four; so that the spaces described by a falling body are proportioned, not simply to the times of falling, but to the *squares* of the times; so that a body falls in ten seconds not merely ten times as far as in one second, but the square of ten, or a hundred times as far.

34. Hence, when bodies fall towards the earth from a great height, they finally acquire prodigious speed. A man falling from a balloon half a mile high, would reach the earth in about half a minute. We seldom see bodies falling from a great height perpendicularly to the earth; but even in rolling down inclined planes, as a rock descending a steep mountain, or a rail car breaking loose from the summit of an inclined plane, we see strikingly exemplified the nature of accelerated motion. A log descending by a long wooden trough down a steep hill, has been known to acquire momentum enough to cut in two a tree of considerable

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How would a guinea and a feather fall in a vacuum? Case of a ball knocked on ice. How much farther will a body fall in two seconds than in one? How are the spaces of falling bodies proportioned to the times of falling?

34. In what time would a man fall from a balloon half a mile high? Where do we see the rapid acceleration of falling bodies exemplified?

size, which it met on leaping from the trough. At a great distance from the earth, the force of gravity becomes sensibly diminished, so that if we could ascend in a balloon four thousand miles above the earth, that is, twice as far from the center of the earth as it is from the center to the surface, the force of attraction would be only one fourth of what it is at the surface of the earth, and a body instead of falling 16 feet in a second would fall only 4 feet. At ten times the distance of the radius of the earth, the force of gravity would be only one hundredth part of what it is at the earth. This fact is expressed by saying, that *the force of gravity is inversely as the square of the distanee from the center of the earth*, diminishing in the same proportion as the square of the distance increases. As the moon is about sixty times as far from the center of the earth as the surface of the earth is from the center, if a body were let fall to the earth from such a distance, (the force of gravity being the square of 60, or 3600 times less than it is at the earth,) the body would begin to fall very slowly, moving the first second only the twentieth part of an inch. Were a body to fall towards the earth from the greatest possible distance, the velocity it would acquire would never exceed about 7 miles in a second; and were it thrown upward with a velocity of 7 miles per second, it would never return. This, however, would imply a velocity equal to about twenty times the greatest speed of a cannon ball.

35. When a body is thrown directly upwards, its ascent is *retarded* in the same manner as its descent is accelerated in falling; and it will rise to the height

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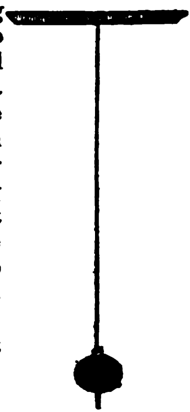
Case of a tree leaping from a trough. How is the force of gravity great distances from the earth? How, 4000 miles off? How, at tl distance of the moon? State the law by which gravity decrease What velocity would a body acquire by falling from the greatest pc sible distance? How far would it go if thrown upward with a veloci *of 7 miles per second?*

hich it would have fallen in order to acquire the y with which it is thrown upwards.

VIBRATORY MOTION. Vibratory motion is that is alternately backwards and forwards, like the of the pendulum of a clock.

Fig. 10.



lulum performs its vibrations l times, whether they are long t. Thus, if we suspend two by strings of exactly equal ;, and make one vibrate over a irc and the other over a large ey will keep pace with each nearly as well as when their ; of vibration are equal. Long ums vibrate slower than short ut not as much slower as the is greater. A pendulum, to seconds, must be four times ; as to vibrate half seconds; ate once in ten seconds it e a hundred times as long as ate in one second, the com- e slowness being proportional *square* of the length. The motion of a pendu- caused by *gravity*. If we draw a pendulum out osition when at rest, and then let it fall, it will d again to the lowest point, but will not stop for the velocity which it acquires in falling will icient, on account of its inertia, to carry it to the height on the other side, (Art. 35.) whence it turn again and repeat the same process; and ere it not for the resistance of the air, and the

hen a body is thrown upwards, in what manner is it retarded? ;h will it rise?

efine vibratory motion. How are the times of vibration of a m? Example. How much longer is a pendulum that vibrates , than *one that vibrates* half seconds? How much longer to friction at the center of motion, the vibration would continue indefinitely.

37. It is the equality in the vibrations of a pendulum, which is the foundation of its use in *measuring time.* Time may be measured by any thing which divides duration into equal portions, as the pulsations of the wrist, or the period occupied by a portion of sand in running from one vessel to another, as in the hour-glass ; but the pendulum can be made of such a length as to divide duration into seconds, an exact aliquot part of a day, and is therefore peculiarly useful for this purpose. Since, also, the pendulum which vibrates seconds at any given place, is always of the same invariable length, it forms the best *standard of measures* by which all others used by society can be adjusted and verified.

38. PROJECTILE MOTION. A body projected into the atmosphere, rises and falls in a curve line, as when a stone is thrown, or an arrow shot, or a cannon ball fired. The body itself is called a *projectile,* the curve it describes, the *path* of the projectile, and the horizontal distance between the points of ascent and descent, the *range.* When an arrow is shot, the impulse, if it were the only force concerned, would carry it forward uniformly in a straight line ; but the gravity continually bends its course towards the earth and makes it describe a curve. An arrow, (or any missile,) will have the greatest range when shot at an angle of 45° with the horizon ; and the range will be the same at any elevation above 45° as at the same number of degrees below 45°. A cannon

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vibrate in 10 seconds than in 1 ? What causes the motion of a pend lum ? Why does it not vibrate forever ?

37. On what property of the pendulum is its use for measuring tim What other modes are there ? Why is the pendulum better than oth modes ? On what principle does it become a standard of measures

38. When is a body called a projectile ? What is the curve describ *called ?* The horizontal distance ? At what angle of elevation mu

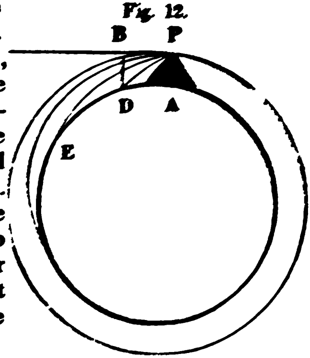
shot at an elevation of 60° will fall at the
distance from the gun as when shot an angle of
0°. Thus, in the annexed diagram, a ship is

Fig. 11.

on from a fort, as she is attempting to pass it.
ball fired at an elevation of 45°, is the only one
reaches the ship: the others fall short, and equally
aimed above and below 45°.

. If a cannon ball were fired horizontally from
op of a tower, in the direction of P B, the range
d depend on the
gth of the charge.
an ordinary charge,
uld descend in the
e P D; with a strong-
arge, it would move
er to the horizontal
and descend in P E.
may conceive of the
being sufficient to
the ball quite clear
e earth, and make it
lve around it in the
e.

Fig. 12.

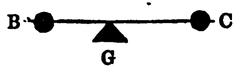


row be shot, to have the greatest range? At what two angles
the ranges be equal.
Explain Figure 12.

SEC. 3.—*Of the Center of Gravity.*

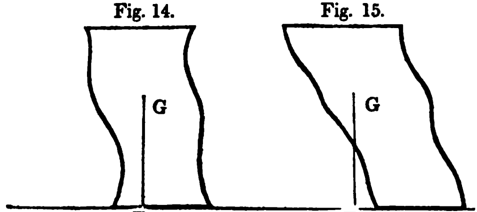
40. The center of gravity of a body is a certai point about which all parts of the body balance eac other, so that when that point is supported, the whol body is supported. If across a perpendicular suppor as G, (Fig. 13,) I lay a wire having a ball at each end, B C there is one point in the wire and only one, upon which th balls will balance each other. This point is th center of gravity of all the matter contained in th wire and both balls. It is as much nearer the large B, as the weight of this exceeds that of C. When tw boys balance one another at the ends of a rail, th lighter boy will require his part of the rail to be a much longer as his weight is less. The center o gravity of a regular solid, as a cube, or a sphere, lie in the center of the body, when the structure of th body is uniform throughout; but when one side i heavier than another, the center of gravity lies towar the heavier side.

Fig. 13.



41. *The line of direction* is a line drawn from t center of gravity of a body perpendicularly to

Fig. 14. Fig. 15.



horizon. Thus, G F, (Fig. 14 or 15,) is the lin rection. When the line of direction falls wit

40. Define the center of gravity. Explain Figure 13.
41. Explain Figure 14. Where is the center of gravity o figure situated?

e, (as in Fig. 14,) or part of the body on which it ts, the body will stand; when this line falls without base, (as in Fig. 15,) the body will fall. At Pisa, [taly, is a celeted tower, called *leaning tower*. It ıds firm,although ›oks as though it ıld fall every moıt; and being veıgh, a view from top is very exci-. Yet there is no ger of its falling, ause the line of ction is far withıe base. To efthis, the lower ; of the tower is le broader than upper parts, and eavier materials. ›se two precautions carry the center of gravity low. ıctures in the form of a pyramid, as the Egyptian amids, have great firmness, because the line of diıion passes so far within the base.

Fig. 16.

2. If we stick a couple of penres in a small bit of wood, and poise n on the finger, or adjust them hat the center of gravity will fall in line of a perpendicular pin, the ıt of the wood will rest firmly on head of the pin, so that the knives ʳ be made to vibrate on it up and n, or to revolve around it, with-

Fig. 17.

ﬁne the line of direction. Explain Fig. 16, Tower of Pisa. are *pyramids so firm ?*

out falling off. A loaded ship is not easily overturned, because the center of gravity is so low, that the line of direction can hardly be made to fall without the base ; but a cart loaded with hay or bales of cotton is, on the other hand, easily upset, because the center of gravity is so high. A stage coach carrying passengers or baggage on the top, is much more liable to upset than it is when the load is all on a level with the wheels. A round ball, however large, will rest firmly on a very narrow base, because the center of gravity (which is in the center of the ball) is always directly over the point of support; and, according to the definition, when this is supported, the body is supported. In the annexed diagram, a heavy ball, connected with the figure, bends under the table, and thus brings the center of gravity of the whole within the base, so that the animal rests firmly on his hind legs.

Fig. 18.

43. Animals with four legs walk sooner and more firmly than those with only two, because the line of direction is so much more easily kept within the base. Hence, children creep before they walk, and the art of walking, and even of standing firmly, requires so nice an adjustment of the center of gravity (which must always be kept over the narrow base

42. Explain Fig. 18. Why is not a loaded ship easily overturned? A cart loaded with hay—a stage coach—a round ball?

43. Why do four legged animals walk sooner than two legged? Why do children creep before they walk?

within the feet,) that it is learned only after much experience. Children at school, also, are sometimes directed to turn out their toes when they walk, and to extend one foot from the other in taking a position to speak, because such attitudes, allowing a broader base for the line of direction, appear more firm and dignified.

44. A boy promised another a cent, if he would pick it up from the floor, standing with his heels close against the wall. But in attempting to pick it up, he pitched upon his face. Performances on the slack rope, which often exhibit astonishing dexterity, depend upon a skillful adjustment of the center of gravity. The process is sometimes aided by holding in the hand a short stick loaded with lead, which is so flourished on one side or the other, as always to keep the center of gravity over the narrow base. Among the ancients, elephants were sometimes trained to walk a tight rope; a feat which was extremely difficult on account of the great weight of the animal.

45. Bodies subject to no other forces than their mutual attraction, and in a situation to approach each other freely, will meet in their common center of gravity. If the earth and moon were left to obey fully their attraction for each other, they would immediately begin to approach each other in a direct line, moving slowly at first, but swifter and swifter, until they would meet in their common center of gravity, which would have its situation as much nearer to the earth as the weight of the earth is greater than that of the moon. So all the planets and the sun, if abandoned to their mutual attraction, would rush together to a common point, which on account of the vast quantity of matter in the sun, lies within that body.

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44. Case of picking up the cent. Performances on the slack rope by men, and even by elephants, explained.
45. Where will *bodies meet by their* mutual attraction? Examples.

Indeed, were all the bodies in the universe abandoned to their mutual attraction, they would meet in their common center of gravity.

SECTION 4.—*Of the Principles of Machinery.*

46. The elements of all machines are found among the *Mechanical Powers*, which are six in number—the Lever, the Wheel and Axle, the Pulley, the Screw, the Inclined Plane, and the Wedge. That which gives motion is called the *power;* that which receives it, the *weight.* The first inquiry is, what power, in the given case, is required just to *balance* the weight. Any increase of power beyond this, would of course put the weight in motion. It is a general principle in Machines, that *the power balances the weight when it has just as much momentum.* Now we may give a small power as much momentum as a great weight, by making it move over as much greater space in the same time, as its quantity of matter is less. One ounce may balance a thousand ounces, if the two be connected together in such a way that the smaller mass, when they are put in motion, moves a thousand times as fast as the larger. If the momentum of the power be increased beyond that of the weight, as may be done by increasing its quantity of matter, then it will overcome the weight and make it move with any required velocity. Whatever structure connects the power and the weight is a machine.

47. THE LEVER. Figure 19 represents a lever of the simplest kind, where P is the *power*, W the *weight*, and

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in the moon and earth, and all the bodies of the solar system—finally, all the bodies in the universe.

46. What are the elements of all Machines? Enumerate the six Mechanical powers. Distinguish between the power and the weight? What is the first inquiry respecting the power? What is a general principle in Machines, respecting *momentum?* How may we give a small power as much momentum as a great weight? How may one *ounce* balance a thousand? What happens when the momentum of *the power* is increased beyond that of the weight? What does any *structure* that connects the power and the weight become?

ɜ *fulcrum*, or point of support. Now P will just ce W when its weight much less as its dis- from the fulcrum is er. For example, if it ree times as far from ılcrum as W, then one l will balance three ; three pounds will balance ; and, universally, in an equilibrium, *the power plied into its distance from the fulcrum, will equal eight multiplied into its distance*. In the present where the longer arm of the lever is three times ength of the shorter, a power of ten pounds will ce a weight of thirty.

Fig. 19.

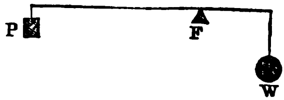
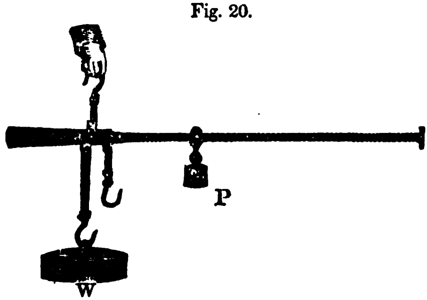


Fig. 20.



This principle is exemplified in a common pair el-yards. The same power (P) is made to bal- different weights of merchandize, (W) by at- ıg W to the shorter and P to the longer arm, and ıg P in a notch that is as much farther from the

Explain Fig. 19. State the general principle of the equilibri- the lever. Examples.
Explain the principle of Steelyards ? How is the same made to balance different weights ? Explain the difference be-

fulcrum as its weight is less than that of the merchandize, W. Steelyards have commonly a smaller and a larger side ; the former being ounce, and the latter quarter-pound notches. On examining such a pair of steelyards, it will be seen that the hook to which the merchandize is attached, is four times as far from the fulcrum, when we weigh on the small, as when we weigh on the large side. Hence, we have to move the counterpoise over four notches on this side to gain as much power as we gain in one notch on the other. The spaces over which the power and weight move respectively, are in the same proportion. Thus, when the counterpoise is made to balance a weight ten times as large as itself, it will be seen, by making the arm of the steelyards vibrate up and down, that the counterpoise moves ten times further in the same time, than the weight does, and of course with ten times the velocity. Hence the momentum of the power and the weight are the same. A crow-bar illustrates the same principle, when a man lifts a weight much heavier than the amount of force he applies, by making that force act at the longer end of the lever. A pair of shears is formed of two such levers combined ; and the nearer we bring the article to be cut to the fulcrum, the greater is the mechanical advantage gained. Two boys differing in size, moving each other at the end of a pole laid across the fence, exemplify the same principle.

49. In the foregoing cases the weight and the po er are on opposite sides of the fulcrum, and it is cal a lever of the *first* kind. When the power weight are on the same side of the fulcrum, but weight nearer to it than the power, it is a lever of

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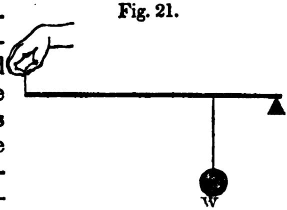
tween the smaller and the larger side. Show that the momen the counterpoise and weight are equal. Examples in a crowba *pair* of shears—boys on a rail.

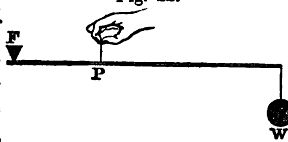
49. Distinguish between levers of the first, second and third ki

Fig. 21.



second kind, as in the following figure. The mechanical advantage gained here is the same as in the first, for the power moves as much faster than the weight as it is more distant from the fulcrum.—When the power and weight are both on the same side of the fulcrum, but the power nearer to it than the weight, it constitutes a lever of the *third* kind, as in figure 22. A door moving on its hinges is a weight, the matter of which, for our present purpose, may be considered as all collected in the center of gravity, which, on account of the regular figure of the door, is the center of the door; and the effects of any force applied to a body are the same as though all the matter was concentrated in the center of gravity, and the force was applied to that point. Now if, in shutting the door, I place my hand on the edge, this point being farther from the fulcrum than the center of gravity, I gain a mechanical advantage, because the power moves faster than the weight; but if I apply my hand nearer the fulcrum than the center of gravity, then the power moves slower than the weight, and operates under a mechanical disadvantage; and as I approach nearer and nearer to the hinges, the door is shut with greater and greater difficulty. In the former case, the door exemplifies the principle of a lever of the second kind; in the latter, of the third. Suppose a ladder to lie on the ground, and it is required to raise it on one end by

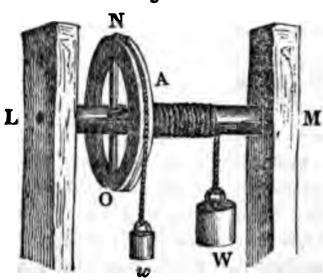
Fig. 22.



How may a door, in shutting, be either of the second or third kind? Example in a ladder.

taking hold of one of the rounds. If I take hold of the lowest round, it will require a great effort to raise it, especially if the ladder is long. This effort will be less and less, until I come to the middle round, where I should neither gain nor lose any mechanical advantage, but should lift the ladder like any other body of the same weight, if raised directly from the ground by a string. If I apply my hand to any round beyond the middle, towards the farther end, I gain a mechanical advantage, and the greater as I approach nearer to the end of the ladder. We shall leave it to the ingenuity of the pupil to account for these several cases.

Fig. 23.



50. THE WHEEL AND AXLE.—The figure represents a wheel, A N O, and axis, L M, where a small power, *w*, balances a greater weight, W. The power required to balance the weight is as much less than the weight as the diameter of the axle is less than that of the wheel. The wheel and axle has a great analogy to the lever, and is indeed little more than a revolving lever. For if the power were applied to the

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50. Explain Figure 23. How much less is the power than the weight? Show the analogy between the wheel and the lever. Explain Figure 24.

of one [illegible]
hed, [illegible]

Fig. [illegible]

capstan [illegible]
s near [illegible]
men [illegible]
nical [illegible]
r exceeds [illegible]
draw up [illegible]

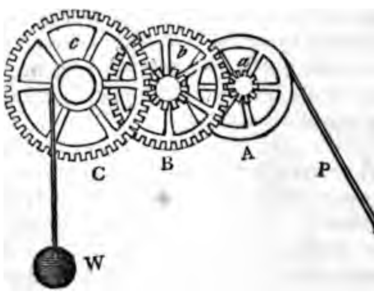
1. W[illegible]
e very [illegible]
s act upon [illegible]
explained. [illegible]
come friction, [illegible]
nd meets [illegible]
es; and in [illegible]
e, a mechanical [illegible]
ortion as the radius [illegible]
axle. Large [illegible]
er than small ones. [illegible]
to *regulate* [illegible]
and see this use exemplified [illegible]
passing a band over a large [illegible]
dy motion, one may [illegible] small

What is the use of [illegible]
d by rolling instead of sliding? [illegible]
h gain most, large or small wheels? [illegible]

wheel of a lathe, and the smaller wheel will revolve as much faster than the larger as its diameter is less. Now by using small wheels of different diameters on the lathe, we may increase or diminish the velocity at pleasure. The same principle is illustrated in a common spinning wheel, and in machinery for spinning cotton.

52. In *clock-work*, there is usually a combination of a number of wheels, where one wheel is connected to the axis of another by a small wheel fastened to the axis, called a *pinion*. Thus, the three wheels, A, B,

Fig. 25.



C, are connected. The power is applied to the wheel A on whose axis in the pinion *a*, the teeth of which (or *leaves*, as they are called) catch into the teeth of B, whose pinion *b* in like manner turns the wheel C. Here the motion of each succeeding wheel is less than the preceding; for if the pinion *a* have 10 leaves, and the wheel B 100 teeth, the pinion in turning once would catch but ten teeth of the wheel, and must therefore turn ten times to turn B once. If the pinion *b* has

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ting velocity. How exemplified in a turner's lathe? In a common spinning wheel.

52. Explain the use of wheels in clock-work. Explain Fig. 25.

also 10 leaves, and the wheel C 100 teeth, then C turns ten times as slow as B and a hundred times as slow as A. By altering the proportions between the number of teeth in the wheel and leaves in the pinion, we may alter the velocity of a wheel at pleasure; and this is the way in which wheels are made to move faster or slower, at any required rate, in clocks and watches. If we apply the power at the other end and let the wheel C act on the pinion *b*, and the wheel B on the pinion *a*, then B will turn ten times as fast as C, and A ten times as fast as B, and a hundred times as fast as C; so that, when the wheels carry the pinions, the velocity is increased; but when the pinions carry the wheels, it is diminished.

53. THE PULLEY. A pulley is a grooved wheel, around which a rope is passed, and is either fixed or movable. Figure 26 represents a *fixed* pulley; and

Fig. 26.

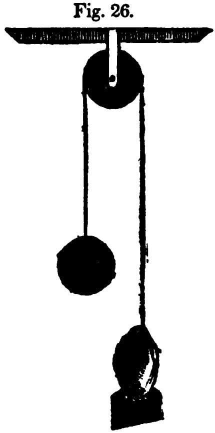


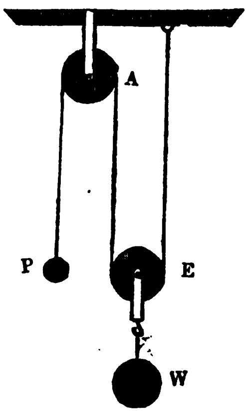
Fig. 27.

Show how the motion is accelerated in one direction and retarded in the other. How may we alter the velocity of a wheel at pleasure?

53. *Define the Pulley.* Name the *two kinds*. What is the use of

here no mechanical advantage is gained, since the power moves just as fast as the weight, and we must remember that it is only when the power moves faster than the weight, that any mechanical advantage is gained. The boy, however, in figure 27, draws himself up by lifting only half his weight, because the two ropes support equal portions of the weight. The principal use of the fixed pulley is to change the direction of the weight. Thus, in drawing a bucket out of a well, it is more convenient to pull downwards by a rope passing over a pulley above the head, than upwards by drawing directly at the bucket. By the *movable* pulley we gain a mechanical advantage, for by this we can give the weight a slower motion than the power has, and can proportionally increase the efficacy of the power. Thus, in figure 28, as both the ropes, A and E, are shortened as the weight ascends, the rope to which P is attached is lengthened by both, and therefore P descends twice as fast as W rises, and the efficacy of the power is doubled. By employing a pulley with a number of grooves (called a block) with a rope around each, we may make the power run off a great length of rope while the weight rises but little, being equal to the combined length by which all the ropes of the block are shortened. Thus, if the block carries twelve ropes, the power is increased in efficacy 12 times. Instead of a single block with a number of grooves, several

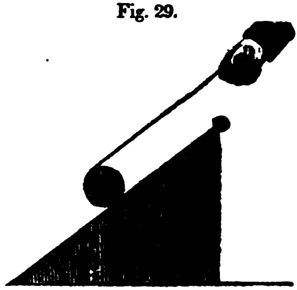
Fig. 28.



the *fixed* pulley? Of the *movable* pulley? Explain the power of a *block of pulleys.*

pulleys with single grooves are combined upon a similar principle. By a block of pulleys, two men will lift a rock out of a quarry a thousand times as heavy as they could lift with their naked hands; but the rope at which they pull will run off a thousand times as fast as the weight rises.

Fig. 29.



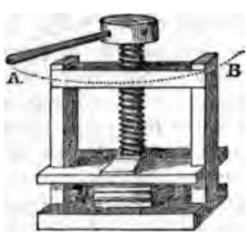
54. THE INCLINED PLANE. The Inclined Plane becomes a mechanical power in consequence of its supporting a part of the weight, and of course leaving only a part to be supported by the power. If a plank, for example, having on it a cannon ball, is laid flat on the ground, it supports the whole weight of the ball. If one end is gradually raised, more and more force must be applied to keep the ball from rolling down the plane; and when the plank becomes perpendicular, a force would be required to sustain the ball equal to its whole weight. We may therefore diminish the effect of gravity, in ascending from one level to another, as much as we please, by making the inclination of the plane small. A builder who was erecting a large edifice, had occasion at last to raise heavy masses of stone to the height of sixty feet. He might have hauled them up by pulleys; but this was inconvenient, and be-

54. How does the Inclined Plane become a mechanical power? Ex-

sides, pulleys are subject to so much friction as to oc casion a great loss of power. He therefore con structed of timbers and planks, an inclined plane si hundred feet long, and conveyed the blocks of ston up them on rollers. As the plane was ten times a long as it was high, it was as easy to roll 1000 pound up the plane as it would have been to draw up 10 pounds by a fixed pulley, But as the plane was te times as long as it was high, the weight would have t pass over ten times the space that it would if it ha been raised perpendicularly by the pulley. In a cases, the mechanical advantage gained by the incline plane is in the same proportion as its length exceed its height. When a horse draws a loaded cart on lev el ground, he has merely the friction to overcome; bu when he drags it up hill, he has beside the friction, t lift a certain part of the load, which part will be great er in proportion as the hill is steeper. If the rise i one part in ten, then he would lift one tenth of the loa continually.

55. The Screw. The screw is represented in t following diagram as act upon a press, which is a v common use that is made c As the screw is turned, it vances lengthwise throu space just equal to the tance between the thr Now if the power be ap directly to the head screw, then, in turnir screw once round, the would move over as more space than the screw advances, as the

Fig. 30.



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ample. How employed in building? What makes it so ha a *load* up hill?

55. Explain Fig. 30. How is the mechanical advanta

ference of the head is greater than the distance between the threads. The mechanical advantage gained is in the same proportion; and we may increase the efficacy of the power either by lessening the distance between the threads, or by increasing the space over which the power moves. If we attach a lever to the head of the screw, and apply the hand at the end, then we make the power move over a space vastly greater than that through which the screw advances, and the force becomes very powerfnl, and will urge down the press upon the books or any thing in press, with great energy.

56. The WEDGE. The Wedge is an instrument used for separating bodies, or the parts of bodies, from each other, as is seen in the common wedge used for splitting rocks or logs of wood. In the kind of wedge in ordinary use, the mechanical advantage gained is greater in proportion as the wedge is thinner. Accordingly, it requires but a small force to drive a thin wedge, but a greater force in proportion as the thickness increases. Cutlery instruments, as knives, axes, and the like, act on the principle of the wedge. When long and proportionally thin, the wedge becomes a mechanical power of great force, sufficient to raise ships from their beds.

57. MACHINES. Machines are compounded of the mechanical powers variously united. We recognize, at one time, the union of the lever with the screw; at another, of the wheel and axle with the pulley; and, at another, of nearly all the mechanical powers together. The following figure represents a machine for hauling a vessel on the stocks, combining the wheel and axle, the screw, the inclined plane and the pulley. Each contributes to increase the efficacy of the

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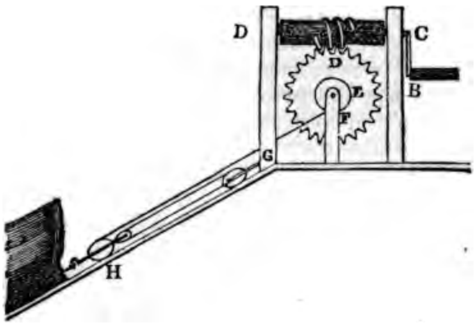
when the power is applied to the *head* of the screw? Also when applied at the end of the *lever?*

56. *What is the Wedge used* for? How is the the mechanical advantage of the wedge increased?

force, and all together make a powerful machine. man applies his hand at B and turns a crank whi

Fig. 31.



acts on the principle of the lever upon the screw at If the space over which the hand moves in one re lution is a hundred times as great as the distance l tween the threads of the screw, then the mechani advantage gained is in the same proportion, and t force with which the screw urges the teeth of t wheel, is a hundred times that applied by the hand the crank. The diameter of the wheel is four tin that of the axle; therefore, the force applied at E four hundred times that at B. This acts on a co bination of pulleys, which, having four ropes, mu ply it again four times, and it becomes sixteen hu dred. The inclined plane is twice as long as it high, and therefore doubles the efficacy of the pow and it becomes three thousand and two hundred tin what it was originally. So that the single force whi a man can exert by means of such a machine is p digious; and if the machine was so contrived (as might easily be) that a pair of horses or a yoke of c

57. How are *Machines* composed? Explain Fig. 31. How the *velocity* of the weight compare with that of the power?

;ead of the man, could turn the machine, the 'ould be adequate to move the largest ship. machine, however, would move the body with e slowness. Its motion, in fact, would be dimin-s much as the efficacy of the power was in-l. This, as we have said before, is a universal le in mechanics; so that we may find the power l by any machine, by seeing how much faster ving force goes than the weight.

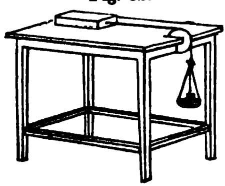
Machines, therefore, gain no momentum: the multiplied into its velocity always equals the multiplied into *its* velocity. But although es do not of themselves generate any force, they us to apply it to much greater advantage—to its direction at pleasure—to regulate its ve--and to bring in to the aid of the feeble powers of he energies of the horse and the ox, of water, nd steam.

FRICTION. The principles of machinery are first gated, on the supposition that machines move t resistance from external causes. Then the e influence of such accidental causes of ir-ity, in any given case, is ascertained and . The two most general impediments to ma-are friction and resistance of the air, which n more or less destruction of force in all ma- Friction arises from the resistance which it surfaces meet with in moving on each other. ly smooth surfaces adhere together by a cer-ce, opposing a corresponding resistance to the of the surfaces on one another; but the as-s which exist on most surfaces occasion a greater resistance. An extreme case is when

Machines gain any momentum? What two products are qual to each other? How do machines aid us?
what *supposition* are the principles of machinery first in-d? What are the two most general *impediments* to machines?

one brush is slid across another, and the hairs interlace. By careful experiments on friction, the following are found to be its principal laws. First, the friction of a body, other things being equal, is proportioned to its *weight*. If a brick is laid on a table, with a string attached to it connected with a scale below, by placing weights in the scale we may ascertain just how much force it takes to drag it off from the table

Fig. 32.



under different circumstances, and this will be the measure of the friction. We should suppose that the friction would be greater on its broad than on its narrow side; but experiments show that it is equal in the two cases, so that *extent of surface* makes no difference when the weight remains the same. We may let the same brick rest on either side, and load it with different weights, equal to its own weight, double, triple, and so on. In all cases, we shall find the friction increased in the same proportion as the weight. Secondly, friction is increased by bodies remaining some time *in contact* with each other; and when the contact is but momentary, as when a body is in very swift motion, the amount of friction is greatly diminished. Thus, when a carriage is in swift motion over a road, it encounters less resistance from friction in passing a given distance, than when it moves slowly. The same is strikingly the case in railway cars.

60. *Rolling* are subject to far less friction than *sliding* bodies. Thus, if a coach wheel be *locked*, that is, made to slide down hill instead of rolling, its

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What *causes* friction? State an extreme case. To what is the friction of a body *proportioned?* How is the amount of friction affected by continued *contact?*

60. Difference between *rolling* and *sliding* bodies? Use of *lubrica*

friction may be so much increased as to check the rapidity of descent in any required degree. Rollers are therefore employed in transporting heavy bodies, to diminish friction; and, for the same purpose, surfaces are made smooth by applying grease, or different pastes, or even water, all of which fill up the inequalities and thus diminish the asperities of the surface. Although friction presents a resistance to machines, yet it has its uses in mechanical operations. It is this which makes the screw and the wedge keep their places; and it is the friction of the surfaces of brick and stone against each other, which gives stability to buildings constructed of them. The wheels of a carriage advance by their friction against the ground. On perfectly smooth ice they would turn without advancing. We could not walk did not friction furnish us with a foothold; and it is for want of friction that walking is so difficult on smooth ice. So rail cars meet with great difficulty in proceeding when the rails have been recently rendered slippery by ice: the wheels turn without advancing. Friction is even employed as a mechanical force, as when a lathe is turned by the friction of a band. Air meets with greater resistance in passing over rough surfaces than water does; for water deposites a film of its own fluid upon the surface over which it moves, and thus lubricates it. Hence water flows in pipes with less resistance than air passes over the surfaces of a rough and sooty chimney.

61. The resistance which bodies meet with in passing through air or water, increases rapidly as the velocity is increased, being proportioned to the *square* of the velocity. Thus, if a steamboat doubles its

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ting substances? Give examples of the *uses* of friction in the screw and the wedge—in the materials of a building—in carriage wheels—in lathes. Which meets with the greater resistance from friction, *water* or *air?*

61. *How is friction proportioned to velocity?* Example.

eed, it encounters not merely twice as much resi
.nce from the water, but four times as much. Th
ıakes it much more expensive to move boats rapid
han slowly, for it would require nine times the for
to triple the speed.

CHAPTER III.

HYDROSTATICS.

PRESSURE OF FLUIDS—SPECIFIC GRAVITY—MOTION OF FLUIDS
WONDERFUL PROPERTIES COMBINED IN WATER.

62. HYDROSTATICS *is that branch of Natural Ph losophy, which treats of the pressure and motion of flui in the form of water.*

SEC. 1. *Of the* PRESSURE *of Fluids.*

63. Water, on account of the mobility of its part may be easily *displaced*, but it is with great difficul *compressed.* If we take a hollow ball of even compact a metal as gold, fill it full of water, plug close, and put it into a vise and compress it, the wa will sooner force its way through the gold than y to the pressure. This is an old experiment, and i to the belief that water is wholly incompressible it is now found that its volume may be reduc smaller dimensions by subjecting it to very great sures. Thus, 30,000 pounds pressure to the inc lessen its bulk one twelfth.

64. *A fluid when at rest, presses equally in al tions.* A point in a tumbler of water, for e: taken at any depth, exerts and sustains th pressure in all directions, upwards, downwa sideways. So that if I attach a string to :

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62. Define Hydrostatics. 63. Is water *compressible?* ?
What force is required to lessen its bulk *one twelfth?*
64. What is the *law* of pressure in all directions? Ex

let it down into water, the weight of the water sts on its upper side is balanced by an equal on its under side. This is the most remark- ›erty of fluids, and is what distinguishes them ›ds, which press only downwards, or in the of gravity.

given pressure, or blow, impressed on any f a mass of water confined in a vessel, is dis- ›qually through all parts of the mass. If I cork into a bottle filled with water, so near hat the cork meets it, the pressure is felt, not n the direction of the cork, or just under it, ll parts of the bottle alike; and the bottle is to break in one part as another, if equally ıroughout, and if not equally strong, it will at its weakest point, wherever that is situ- we insert into a large vessel of water a adder, and then press upon r surface of the water with fits it close, as in figure 33, der will indicate an equal on all sides. A is the lid the jar, water tight, and is o the top of the fluid; B is blown bladder, kept in its a leaden weight resting on ›m of the vessel. If a thin l is substituted for the blad- ›ressing down the lid, it will ›n into minute fragments, showing an equal on all sides. The same effects would follow › pressure applied at the side, or any other he vessel, instead of the top.

Fig. 33.

his principle operates with astonishing power *drostatic press.* Figure 34 represents a press

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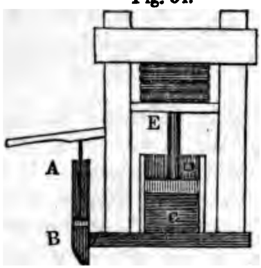
is a *pressure on* any part of a confined mass of water dis- *Example.* *Explain* Fig. 33.

made of a strong frame of timbers, having

Fig. 34.



cylinder, C D, full o
and opening into a
cylinder, A B, in w
plug (called a *pis*
moved up and down
lever attached to
D is another piston
when forced upward
es upon a *follower*
which communicat
force to a pile of boo
posed in the proc
binding. Now if I apply my hand to the le
force down the piston in AB upon the sur
the water, with whatever force it presses up
surface of the fluid in the small cylinder, th
is exerted on all parts of the water in the larg
der, and consequently upon the piston D to
upwards against E. Suppose the number of
inches in the bottom of the piston E, is a th
times as great as in that of the piston at B; t
urging B forward with a force equal to one h
pounds, I should communicate to E a pressure
hundred thousand pounds. The water in th
cylinder would descend a thousand times as m
that in the large cylinder rose, so that the
through which the accumulated force could ac
be very small; still it would be sufficient fo
articles as books, where the whole compressio
small. Since there is no loss from friction
machine, a man can by means of it exert a
power than by any other to which he can ap
own strength. He can by means of it crush

66. Describe the *Hydrostatic Press.* Suppose the number
inches in the larger piston is a thousand times as great
smaller? Uses of the Hydrostatic Press?

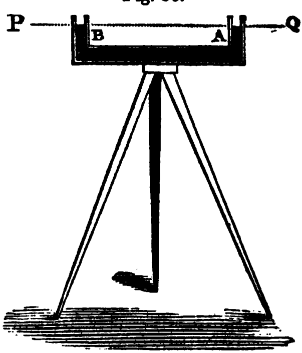
and cut in two the largest bars of irou. The hydrostatic press is much used as an oil press, as in extracting oil from flax seed ; and also for packing hay, cotton, and other light substances.

67. *The surface of a fluid at rest is horizontal.* This property is applied to the construction of the FLUID LEVEL, used by carpenters, masons, and other

Fig. 35.

workmen. It usually consists of a flat rule, having a horizontal glass tube on the upper side, containing alcohol (which is preferred to water because it never freezes.) The tube is not quite full of the fluid, so that when laid on its side a bubble of air floats on the upper surface. When this is exactly at a given mark near the middle, then the surface on which the rule is laid is level. Figure 36 represents a levelling staff much used in surveying and grading lands. The liquid in the two arms of the tube at A and B being precisely on a level, any two remote objects, P and Q, may be brought accurately to the same level by *sighting* P with the eye at A ; that is, bringing it into the same horizontal line with the surfaces of A and B, and then sighting Q in the same manner.

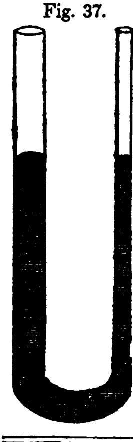
Fig. 36.



67. How is the *surface* of a fluid when at rest ? Describe the *fluid-level* and the *levelling staff.*

68. *The pressure upon any portion of fluid, is proportioned to its depth below th* we let down a junk bottle into the sea, on all sides of it would continually incr scended, until it would be sufficient to c great strength, however, would enable prodigious pressure. When an empty l closely, is let down to a great depth, c up, it is found full of salt water, and yet disturbed. At a certain depth, the pre cork is such as to contract its dimensi being equally pressed on all sides, it is ı Its size being contracted, the water rı sides; but on rising to the surface, the again to its former bulk. When the sto admit of compression, the water someti through its pores and thus fills the bottle. at a great depth, have the dered so heavy by the gre water forced into it, that v to pieces their parts do n pressure of water on a squa depth of eight feet, is 500 having the same amount a ery eight feet of descent, it prodigious. At the depth is no less than 330,000 poı square foot.

Fig. 37.

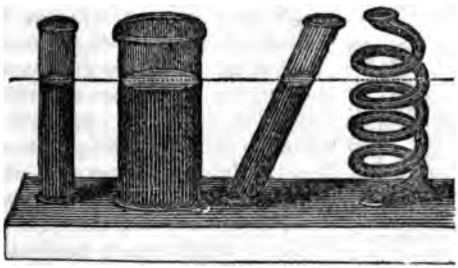


69. *Fluids rise to the sa opposite arms of a bent tube.* be a bent tube: if water b either arm of the tube, it w same height in the other ar material what may be the s

68. How is the pressure of a column of fluid at Example in a *junk-bottle*. What happens to a corke *great* depth? What is the pressure on a square foo *eight* feet,—and a *mile*?

inclination of the opposite arms. Figure 38 represents a variety of vessels and tubes open at top but com-

Fig. 38.



municating with a common cistern of water below. If we pour water into any one of these, so as to fill it to any height, the water will be at the same height in each of the others. Hence, water conveyed in aqueducts, or running in natural confined channels, will rise just as high as its source, and no higher. Between the place of exit and the spring, the ground may rise into hills and descend into valleys, and the pipes which convey the water may follow all the irregularities of the country, and still the water will run freely, provided no pipe is laid higher than the level of the spring.

70. *The pressure of a column of water upon the bottom of a vessel, depends wholly upon the height of the column, without regard to its shape or size.* In figure 38 the pressure on the bottom of the cistern will be the same whether one tube is attached, or the whole number, or the vessel itself is raised to the same height all the way of the same size as at the bottom,

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69. Fluids in the opposite arms of a *bent tube?* What does Fig. 38 represent? How high will water in an *aqueduct* rise?

70. Upon what *does the* pressure of a column of fluid on the bottom

or even if swelled out like a funnel, so to be larger above than below. On this principle is fo the hydrostatic paradox—that *any quantity of however small may be made to rai weight however great.* Figure 3 resents a bellows having on on an open tube communicating w On pouring water into the tub bellows being full) it will force top of the bellows although loade heavy weights. A wine glass of for example, will raise the boy stand on the bellows, and would bly lift a weight many hundred as great. The principle is the as in the hydrostatic press. the weight of the column of wa fords the power that acts on the larger end of th lows, as in the press the force of the piston i small cylinder acts on that in the larger.

Fig. 39.

SEC. 2. *Of Specific Gravity.*

71. SPECIFIC GRAVITY *is the weight of a bod pared with another of the same bulk, taken as a ard.* Water is the standard for solids and liq common air for gases. The specific gravity mineral, for example, or of alcohol, is its weight pared with that of a mass of water of exactl same volume; the specific gravity of steam weight compared with that of the same volume mospheric air. We must know, then, what an volume of the standard would weigh. This is

of a vessel depend? State the principle called the *hydrostatic p* Explain Fig. 39.

71. Define *specific gravity.* What is the standard for *solids for liquids*—what for gases? What must we know in order to

tained in the case of a solid, by finding how much less the body weighs in water than in air; and, in the case of a liquid or a gas, by weighing equal volumes of the body and of air. Wishing to know how much heavier a certain ore, which I suspected to be silver, was than water, I tried to compare its weight with that of an equal bulk of water; but the ore being of very irregular shape, I found great difficulty in measuring it accurately to find the number of solid inches in it, so that I could weigh it against the same number of inches of water. But learning that a body when weighed in water weighs as much less than when weighed in air, as is just equal to the weight of the same volume of water, I attached a string to the ore, hung it to one arm of the balance, and found its weight to be 4.75 ounces; and then bringing a tumbler of water under the suspended ore so as to immerse it, I found it did not in this situation weigh as much as before, but I had to take out 1.25 ounces to restore the balance. This, then, was what the ore lost in water, and was the weight of an equal volume of water. Now I have found that the ore weighs four ounces and three quarters, while the same bulk of water weighs only one ounce and a quarter. I see, therefore, at once, that the ore is about four times as heavy as water; but to find the exact specific gravity, I see how many times the weight of the ore is greater than that of an equal volume of water, by dividing 4.75 by 1.25, which gives 3.8 as

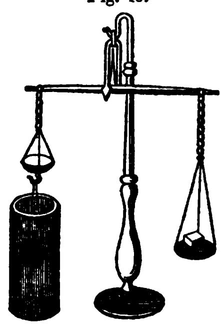

Fig. 40.

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specific gravity of a body? Describe the way of finding the specific gravity *of an ore—also of alcohol*—also of *carbonic acid.*

the exact specific gravity of the ore. I conclude, therefore, that it cannot contain much silver, if any; otherwise it would be heavier. Again, desiring to find the specific gravity of some alcohol (which is better in proportion as it is lighter,) I took a small phial, counterpoised it in a pair of delicate scales, and poured in water gradually till I had introduced exactly 1000 grains. I then set the phial on the table, and placing my eye accurately on a level with the surface of the water, I made a fine mark with a small file just round the water line. On emptying out the water and filling the phial to the same mark with the alcohol, I found the weight of it to be 815 grains. I therefore inferred that its specific gravity was 815, water being 1000. Having now my phial ready, I filled it to the mark successively with half a dozen different liquors, some lighter and some heavier than water, and thus found the exact specific gravity of each. Finally, I had the curiosity to see which is the heaviest, common air, or that sort of air which sparkles so briskly in soda-water, and in bottled beer, called carbonic acid. I therefore weighed a light glass bottle, which, as we commonly say, was empty, but was really filled with common air, and then withdrawing the air from the bottle by means of a kind of syringe which sucked it all out, I then turned the stop-cock attached to the mouth, shut the bottle close, and weighing it again, found it had lost 40 grains, which was the weight of the air. At last I filled the bottle with carbonic acid instead of air, and weighing again, found the vessel now weighed 60 grains more than before. This was the weight of the carbonic acid; and now having found that when we take equal bulks of common air and carbonic acid, the latter weighs 60 grains, while the former weighs only 40, I infer that the carbonic acid is one half heavier than common air; that is, its specific gravity is 1.5. By a similar process, I fr that hydrogen gas, one of the elements of water, is more than thirteen times as light as air, being the lightest of all known bodies.

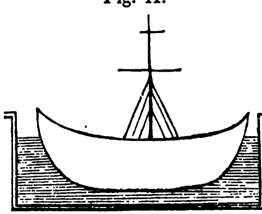
72. A body *floats in water at any depth*, when its specific gravity is just equal to that of water. The human system is a little heavier than water, and therefore tends to sink in it; but if we strike the water downwards, its reaction will keep us up, acting as it does in a direction opposite to that of gravity. A very slight blow upon the water is sufficient to balance the downward tendency, and therefore *swimming* becomes an easy matter when skillfully practiced. As we lose in water as much of our weight as the same bulk of water would weigh, and that is nearly the whole, it is only the slight excess of our weight which we have to sustain in swimming. Indeed, if we could keep our lungs constantly inflated, we should require no reaction to keep us up, but should float on the surface. Dr. Franklin when a boy swam across a river by the aid of his kite, which supplied the upward force necessary to sustain him, instead of the reaction of the water. Fishes are nearly of the same specific gravity as the water in which they live. They are supplied with a small air-bladder, which they have the power of compressing and dilating. When they wish to sink they compress this bladder, and their specific gravity is then greater than that of the water; and they easily rise again by suffering the badder to dilate. Birds float in the atmosphere on similar principles. Being but little heavier, bulk for bulk, than the air, very slight blows with their wings create the reaction in an upward direction, which is necessary to sustain them; stronger blows cause the reaction to overbalance

72. When does a body *float* in water? How is the body supported in *swimming?* How did *Dr. Franklin* swim across a river? How do *fishes* ascend and descend? How do *birds* fly?

the excess of their specific gravity over that of th
and they rise with the difference.

73. When a body *floats on the surface of wat* displaces as much weight of water as is equal t own weight. Thus, if I place a wooden block we ing four ounces in a tumbler of water even full, four ounces of the water will run over, as we ascertain by collecting and weighing it. Upon principle ships float on water. In proportion a lade the ship, it sinks deeper and deeper, the w of water displaced always being exactly equal t weight of the ship and cargo. The actual weig the ship and cargo may be easily ascertained on principle; for if we float the ship into a dock of kn size containing a given quantity of water, the w of the ship and cargo may be determined from the of the water in the dock. A boy wished to find tonnage of his boat. therefore loaded it as h as it would swim, and transferred it to a small which he had made, a which he knew the dimensions. He then p into the box a pound of ter at a time, and wh had settled to a good he made a mark at the water line, and adding pound of water at a time, he thus had marks at d ent heights, from one pound up to twenty. He f that four pounds of water were amply sufficie float his boat, and when the boat was laid up the water rose on the sides to the nineteenth n Consequently the boat had raised the water fi

Fig. 41.



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73. How much water does a floating body *displace?* Ex Method of finding the tonnage of a *ship?* How did the *boy* fi *tonnage* of his boat?

marks, and its weight was of course fifteen pounds; for it weighed just as much as the water would have weighed which it would have taken to raise the level from the fourth to the nineteenth mark.

Sec. 3. *Of the* Motion *of Fluids.*

74. That part of Hydrostatics which treats of the mechanical properties and agencies of running water, is called *Hydraulics*, and machines carried by water, or used for raising it, *Hydraulic machines*. It embraces what relates to water flowing in open channels, as rivers and canals; or in pipes, as aqueducts; or issuing from reservoirs in jets and fountains; or falling, as in dams and cascades; or oscillating in waves. A river or canal is water rolling down hill, and would be subject to the same law as other bodies descending inclined planes, were it not for the numerous impediments which oppose the full operation of the law. Now a body rolling down an inclined plane has its motion constantly accelerated, like a body falling perpendicularly, gaining the same speed in descending the plane that it would in falling through the perpendicular height of the plane. Hence when a body rolls down a long plane without obstruction it soon acquires an immense velocity, as is seen in a rock rolling down a long hill. In the same manner, a body of water descending in a river constantly tends to run faster and faster, and would soon acquire a most destructive momentum, were it not retarded by numerous counteracting causes, the chief of which are the friction of the banks and bottom, and the resistance occasioned by its winding course, every turn opposing an impediment of more or less force. By such a circuitous route two benefits are gained—the rapidity of the

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74. Define *Hydraulics*. What subjects does it *embrace?* Are *rivers* subject to the laws of falling bodies? What benefits arise from

stream is checked, and its advantages are more widely distributed. A river flows faster in the channel, towards the middle, than near the banks, because it is less retarded by friction; and during a freshet the rapidity is greatly increased, because since the waters that are piled on the original bed are subject to little friction, they exhibit something of the accelerated motion of bodies rolling freely down inclined planes. A very slight fall is sufficient to give motion to water where the impediments are slight. The Croton Aqueduct, that waters the city of New York, falls but one foot in a mile. Three feet fall per mile makes a mountain torrent. Some rivers do not fall more than 500 feet in 1000 miles, or a foot in two miles, and require a number of days, or even weeks, to pass over this distance.

75. The Aqueducts which the ancient Romans and Carthagenians built for watering their cities, were among the greatest of their works, some of which have remained until the present day. Large streams were conducted for many miles, sometimes not less than a hundred, in open canals, carried through mountains and led over deep valleys, on stupendous arches of masonry. Some have supposed that the ancients must have been unacquainted with the principle, that water flowing in pipes will rise as high as its source, since, had they known this, they might have conveyed water in pipes instead of such expensive structures; these might have ascended and descended, following all the inequalities of the face of the country, provided they were in no part higher than the head or spring. It is found, however, that they were acquainted with the principle, but prefer-

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the *circuitous* routes of rivers? What part of a river flows *fastest*? Why do rivers run so swift during a *freshet*? What *fall* per mile have the Croton Water Works?

75. What of the Aqueducts of the Romans and Carthagenians?

onstruct their aqueducts of open channels rath- 1 pipes. Suitable pipes, at that age, would een very costly. They are apt also to become 1; and although they might have followed the in- ies of hills and valleys, yet when they descend- ascended far from the general level, they would ged to encounter an enormous pressure, since, lumn of water, the pressure on any part is pro- ed to the depth below the surface of the wa- creasing five hundred pounds to the square foot ry eight feet of descent. A pipe, therefore, fifty ep and full of water, would have to bear a pres- t the lower part of more than three thousand to the square foot, and must be made propor- r strong, and would be apt to leak at the joints. it the present day, it is found more eligible to cities by open aqueducts than by pipes, as is 1 the new Croton Water Works for watering the New York. Here an artificial river of the water is conveyed from the county of Westches- rty-one miles above the city, to a vast resevoir e of holding 150,000,000 of gallons, where it has mity to deposit any sediment or impurities it ive taken up on its way, and to absorb air, which it life and briskness. From the reservoir it is ated to all parts of the city in pipes, affording ole supply for domestic uses, for watering and ig the streets, and for extinguishing fires.

When a plug is removed from the top of one of ies of an aqueduct, the water spouts upward in for, since water thus situated tends to rise as s its source, it will spout to that height when ined. At least it would ascend to that height

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e ancients acquainted with the principle that water ascends vel of its source? Describe the Croton Water Works.

hy does water *spout* from a pipe of an aqueduct? How high out?

were it not for the resistance of the air, which pre vents its attaining that full height. It is on this prin ciple that *fountains* are constructed. If we open a vent in the side of a water-pipe, so as to let the je out obliquely, it will form the curve of a parabola and by letting out the jet through different orifices the curves may be varied, and beautiful and pleasing figures exhibited, as is shown at the Park Fountain in the city of New York.

77. In building tall or deep cisterns, we must re member, that the pressure on any part of the cister iucreases with the depth, and hence that the lowe parts require to be made stronger and closer than th upper, else they will either burst in pieces or leak A philosopher wishing to provide a constant supply of water near his house, constructed a large cister six feet high, and contrived to convey a small strea of water to the top which kept it always full and run ning over by a waste-pipe. In the side of the cister he inserted two large stop-cocks of equal size, th first, one foot, and the other four feet from the top supposing that he might, in a given time, draw off eithe one gallon or four gallons; but he was surprised to find that he could obtain from the lower stop-cock only *twice* as much as from the upper. How, thought he is this consistent with the principle that the pressur is proportioned to the depth? If it presses agains the side of the cistern at the lower level four times a much as at the upper, why do not four times as mar gallons run out when the stopper is opened? On r flection, however, he perceived that the pressure the side must be proportioned to the *momentum*, whi depends on two things—the quantity of matter a the velocity; and of course that twice the quantity

77. How must we provide for the *strength* of a pipe at differ *heights*? Relate the story of the philosopher drawing water from a tern. To what is the quantity of water discharged from a cistern

water flowing with twice the velocity, would have just four times the momentum. Hence he learned the grand principle, that in a column of water kept constantly full, the quantity discharged from any orifice in the side, is proportioned to the *square root* of the depth below the surface of the fluid. So that, to draw off twice as much, we must make the opening four times as deep, and to draw off three times as much, as must make it nine times as deep.

78. The philosopher tried another experiment with his cistern. He turned off the run of water that supplied the cistern, and then opened the upper stopcock, and found it took just five minutes to draw off the water to that depth. He then let in the run that supplied the cistern and kept it constantly full. Now opening the same orifice again, and drawing off for five minutes more, he found that he caught just twice as much water as before. From this he inferred, that if a vessel discharges a certain quantity of water in emptying itself to a certain level, it will discharge twice as much in the samé time, when the vessel is kept constantly full.

79. Water issues from the bottom or side of a vessel with the same force that it would acquire by falling through the perpendicular height of the column. It would therefore seem to make no difference whether we let water fall upon a water-wheel from the top of a cistern, or whether we raise a gate at the bottom of the column and let the water issue so as to strike the wheel there, since it would strike the wheel in both cases with the same velocity, except what might be lost in the falling column by the resistance

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different depths *proportioned?* How much lower must we go to double the quantity?

78. What *other* experiment did he try? How much more is discharged when the vessel is kept constantly full?

79. With what *force* does water issue from the bottom or side of a vessel? Does *it make any* difference whether water falls upon a

of the air. A water-fall like that of Niagara, where an immense body of water rolls first in *rapids* down a long inclined plane, and then descends perpendicularly from a great height, affords one of the greatest exhibitions of mechanical power ever seen. The Falls of Niagara contain power enough to turn all the mills and machinery in the world. They waste a greater amount of power every minute, than was expended in building the pyramids of Egypt; for, in that short space of time, millions of pounds of water go over the falls, and each pound by the velocity it gains in falling first down the rapids, and then perpendicularly, acquires resistless energy. Water falling one hundred feet would strike on every square foot with a force of more than six thousand pounds.

80. Man imitates the power of the natural waterfall when he builds a dam across a stream, raising it above its natural level, and then turning aside more or less of it into a narrow channel, makes it acquire momentum while regaining its original level. When it has gained the requisite force, he turns it upon a water wheel usually of great size, from which, by means of machinery, the force is distributed wherever it is wanted, and so applied as to do all sorts of work. When a run of water first strikes a wheel at rest, it strikes it with its full force; but as the wheel moves before it, the effect of the force is diminished, and if the wheel acquired the same velocity as the stream, the force would become nothing. The wheel is retarded by making it do more and more work, or carry a greater weight, until it acquires a uniform motion at a certain rate, which ought to be that at which the force of the stream produces the greatest effect. This is

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wheel from the *top*, or issues upon it from the *bottom?* What of the Falls of Niagara?

80. When does man *imitate* the water-fall? With what force does a run of water *first* strike a wheel? How when the wheel is in motion?

in some cases when the wheel moves half as fast as the stream. That a current of water or of wind strikes an object with less force when the object is moving the same way, is a general principle. Thus, when a steam-boat is moving directly before the wind, she would derive little aid from sails unless the wind were high, for she would "run away from the breeze;" that is, the wind would produce no effect any farther than its velocity exceeded that of the boat, and if it were just equal to that, the effect would be absolutely nothing. A man in a balloon carried forward by a wind blowing a hundred miles an hour, would speedily acquire the same velocity with the wind, and therefore appear to himself to be all the while in a calm. Although the earth is constantly revolving round the sun with inconceivable rapidity, yet as we have the same velocity we seem to be at rest.

SEC. 4. *Of the Remarkable Properties combined in Water.*

81. Water combines in itself a variety of useful properties, all designed for the benefit of man. First, *Natural History* leads us to contemplate it in its various aspects. It covers about three fourths of the globe, and is distributed into oceans, seas, and lakes, rivers, springs, and atmospheric vapor. By the agency of heat, water is constantly rising in vapor on all parts of the ocean. This mingles with the air in an invisible elastic state, being separated in the process of evaporation from its salt and every other impurity. More or less of it is conveyed over the land by winds, and falls upon it in dew, and rain, and snow. A part

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In what case does the stream produce its greatest effect? Example in a steam-boat. How would a man in a balloon appear to himself to be situated when moving with the *same velocity* as the wind?

81. What *part* of the earth is covered with water? In what different *forms*? What benefits flow from *rivers*? Also from the ocean?

of this filters through the sand, runs down in th vices of rocks, and collects in pure fountains below the surface, where it may be easily reac almost every place, by digging wells. In v places it flows out by its own pressure in sprin streamlets, which unite in rivulets, and these ers, which return the water to the sea. But ri they run are made to impart fertility, and to furn avenue by which vessels and steam boats may trate into the heart of every country, and con the remotest cities the riches of every clime. ers furnish an entrance into the interior of cou so the ocean forms the great highway betwe tions, and unites all nations in the bands of com Still further, to serve the grand cause of benev the ocean is filled with living beings innum which are not, like land animals, confined to th face, but occupy the depth of at least six hundre and thus enjoy a far more extensive domain th part of the animal creation that inherits the lan

82. Secondly, *Chemistry* regards water wi less interest than Natural History. Its very *co tion* is admirable, being constituted of two subst oxygen and hydrogen, which, when united wit are separated in the gaseous form, and each po es the most curious and wonderful properties. gen is found as an element in nearly all bodies ture; it is the part of atmospheric air, which tains all animal life and supports all fires; an the most active agent in producing all the ch of matter which take place both in nature an Hydrogen gas is the most combustible of all b and is in fact what we see burning in nearly sort of flame. As a *solvent*, water performs the useful service to man, removing every impurity his clothing or his person, dissolving and p

82. What is the *composition* of water? What of oxygen and *gen?* What of water as a *solvent*? Of the different states

ing his food, and entering largely into nearly all the processes of the arts. By the different *states* which water assumes, of ice and snow and vapor, it performs important offices in the economy of Nature, as well as in its native state of a liquid. These changes of state regulate the temperature of the atmosphere, and preserve it from dangerous excesses both of heat and cold. On the one hand, on the approach of winter in cold climates, water changes to ice and gives out a vast amount of heat that kept it in the liquid state; and on the approach of summer, to check the too rapid increase of temperature, the same heat which was given out when water was changed into ice, is now absorbed and withdrawn from the atmosphere, as ice is changed back to water. Moreover, during the heat of summer, the evaporation of water, a very cooling process, checks the tendency to excess of the heat of the sun, and guards us from all danger on that hand. Ice, by covering the rivers, keeps them from freezing except on the surface; and snow is a warm and downy covering thrown over the earth, to protect the vegetable kingdom by confining the heat of the earth.

83. Thirdly, it is the province of *Physiology* to con template the relations of water to the vegetable and animal kingdoms. Water is the chief food of plants, which it nourishes, either by supplying a part of their elements, or by dissolving their nutriment, and thus preparing it for circulation; and hence water is indispensable to the life and growth of all vegetables. To animals and man, it furnishes the best and only necessary beverage; it is the medium by which our food is prepared; and it acts medicinally in various ways, both internally and externally.

How does it check the *cold* of winter and the *heat* of summer? Useful properties of *ice* and *snow*?

83. *What are the relations* of water to the *vegetable* kingdom? What to *animals* and *man*?

84. Finally, the *Mechanical* relations of water, as those we have been considering in the prece pages, are hardly less remarkable and important t the rest. By its *mobility*, it maintains its own le and keeps itself within its precribed bounds; by *buoyancy*, it furnishes a habitation for numerous tri of fishes, and lays the foundation of the whole ar navigation; by its *pressure* in all directions, it gi the first indication of containing great mechan energy, which is more fully developed in the mense force of running water, which may be reg ed as a repository of power kept in readiness for use of man; and, finally, by its property of be converted into *steam*, it discloses a new and in haustible fountain of mechanical force, which may employ in any degree of intensity to perform humblest and the mightiest of his works.

CHAPTER IV.

PNEUMATICS.

PROPERTIES OF ELASTIC FLUIDS—AIR PUMP—COMMON PUMP-PHON—BAROMETER—CONDENSER—FIRE ENGINE—STEAM AN PROPERTIES—STEAM ENGINE.

85. PNEUMATICS *is that branch of Natural Phil phy which treats of the pressure and motion of ela fluids.* Elastic fluids are those which are capabl contracting or dilating their volume under diffe degrees of pressure. They are of two kinds, *g* and *vapors*. Gases constantly retain the elastic visible state; vapors remain in this state only w heated to a certain degree, but return to the lic

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84. Advantages of its *mobilty*—of its *pressure*—of its capacity o ing converted into *steam*.

85. *Define* Pneumatics. What are elastic fluids? State the *kinds* and *distinguish* between them. What two elastic fluids

state when cooled. Common air is a gas, steam a vapor. Although there are many different gases and vapors known to Chemistry, yet air and steam are the elastic fluids chiefly regarded in Natural Philosophy. Air and steam are both commonly invisible; but air, when we look through an extensive body of it, appears of a delicate blue or azure color, which habit leads us to refer to distant objects seen through it. It is not the distant mountain that is blue, but the air through which we see it. Air also sometimes becomes visible when ascending and descending currents mix, as over a pan of coals, or a hot chimney, when we see a wavy appearance, which is air itself. Vapors also exhibit naturally some variety of colors, as yellow and purple; but the vapor of water or steam is usually invisible. We must carefully distinguish between elastic vapor and the *mist* which issues from a tea kettle. This is vapor *condensed*, or restored to the state of water, and it is only at the mouth of the tea-kettle, where it is hot, that it is in the state of steam, and there it is invisible.

86. The general principles of mechanics apply to liquids and gases, as well as to solids, all bodies being subject alike to the laws of motion; but the property of *mobility of parts*, which characterizes liquids, and of *elasticity* which characterizes gases and vapors, gives them severally additional properties, which lay the foundation of hydrostatics and pneumatics. Although we do not usually *see* gases and vapors, yet we find in them properties of matter enough to prove their materiality. In common with solids, they have impenetrability, inertia, and weight; in common with liquids, they are subject to the law of equal pressure in all directions, and when confined, they transmit the

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chiefly regarded in Natural Philosophy? When is air visible? Are vapors ever visible?

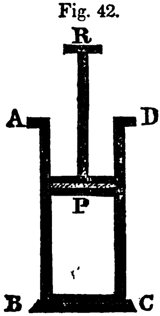
86. Do the general principles of Mechanics apply to liquids and

effects of a pressure or blow upon any one part of the vessel, to all parts alike ; but in their elasticity, they differ from both solids and liquids. Since air and steam are the elastic fluids with which Natural Philosophy is chiefly concerned, we shall consider each of these separately.

SEC. 1. *Of Atmospheric Air.*

87. We may readily verify upon atmospheric air, the various properties of an elastic fluid. Its impenetrability, or the property of excluding all other matter from the space it occupies, will be manifested if we invert a tall tumbler in water. It will permit the water to occupy more and more of the space as we depress it farther, but will never cease to exclude the water from a certain portion of the tumbler which it occupies. We may render this experiment more striking, by employing a glass cylinder and piston, as is represented in Fig. 42. Let A B C D represent a hollow cylinder, made perfectly smooth and regular on the inside, and P a short solid cylinder called a *piston*, moving up and down in it air tight, and R the piston-rod. Now when we insert the piston near the top of the cylinder, the space below it is filled with air. On depressing the piston, the air, on account of its elasticity, gives way and we at first feel but little resistance ; but as we thrust it down nearer to the bottom, the resistance increases, and finally be

Fig. 42.



gases ? What property characterizes liquids, and what solids ? What properties of matter have gases and vapors ?

87. Show how air is proved to be material. Explain Figure 42. State the different principles which this apparatus is capable of prov

omes so great that we cannot depress it any farther y the strength of the hand. If we apply heavy eights, we may force it nearer and nearer to the ottom of the cylinder; but no power will bring it into ontact with the bottom. This experiment may be o varied as to prove several things. First, it shows at air is impenetrable; secondly, that it may be in- efinitely compressed—all the air of a large room ight be reduced to a thimble-full, and on removing he pressure, it would immediately recover its original olume; thirdly, that the resistance increases the nore it is compressed. We will graduate the cylin- ler into a thousand equal divisions, by horizontal narks numbered from the bottom upwards from one o one thousand, and place on the pan at the top of he piston-rod a few grains, so as just to overcome the riction of the piston against the sides of the cylinder. We will now put on weights successively, until we have sunk the piston half way, when the air occupies five hundred instead of a thousand parts of the cylinder. If we double the weight, it will not carry the piston the same distance as before, that is to the bottom, but only through half the remaining space, so that the air now occupies one fourth of the capacity of the cylin- der. If we double the present weight, it will again be compressed one half, so as to fill but an eighth part of the cylinder. We find, therefore, that a double force of compression, always reduces to half the form- er volume. This law is expressed by saying, that *the volume of a given weight of air is inversely as the com- pressing force.*

88. Air has the property of *inertia*. It remains at

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ing. How is the volume of a given weight of air proportioned to the compressing force?

88. Why has air the property of inertia? State the experiment which shows that air has weight. Why is air called a fluid? Have the particles of *elastic fluids* any cohesion?

rest unless put in motion by some force, and continues to move until some adequate force stops it. When put in motion by any moving body, it destroys just as much motion in that body as it receives from it; and it loses its motion only as it imparts the same amount to some other matter. A large body moving swiftly through the air meets with great resistance; but whatever motion it loses, it imparts to the air, which might be sufficient to produce a high wind. Air also has *weight*. If we balance a light bottle, containing a hundred cubic inches, in a delicate pair of scales having just pumped out all the air from the bottle, and then open the stopper, and admit the air again, we find the vessel has gained in weight 30½ grains. We call air and all other gases and vapors *fluids*, because their particles move so easily among themselves. The particles of elastic fluids have no cohesion, but on the other hand, have a mutual repulsion, which causes them to fly off from each other as soon as the compressing force is removed or diminished.

89. The lower portions of air which lie next to the earth, are pressed by the whole weight of the atmosphere, which is found to amount to the enormous force of 15 pounds upon every square inch; or above 2,000 pounds upon a square foot. This force would be insupportable to man and animals, were it not equal in all directions, entering into the pores of bodies, and thus being everywhere nearly in a state of equilibrium. It is only when we withdraw the air from a given space, so as to leave the surrounding air unbalanced that we see marks of this violent pressure.

90. THE AIR PUMP. Various properties of the air are exhibited by this beautiful and interesting apparatus. A simple form of the Air Pump is shown in fig

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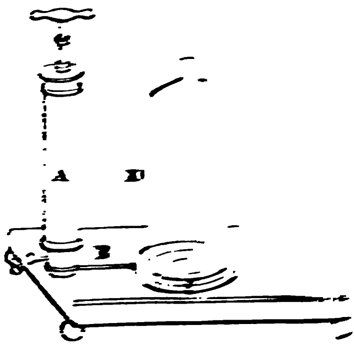
89. What is the pressure of the atmosphere upon a square inch, and square foot? Why is it not insupportable to man?

43. A represents [illegible] [illegible] ving up and [illegible]

[illegible]



ates by an open [illegible]), opening into the [illegible] el ground at the [illegible] pump air-tight. At [illegible] a small [illegible] closes a passage [illegible] be let into the receiver [illegible] by the pump.

In order to understand [illegible] air from the receiver, [illegible] first to learn the [illegible] contrivance by which [illegible] way, but prevented [illegible] A common hand bellows [illegible] in the little clapper on the [illegible] bellows is opened, the [illegible] in; and when the bellows [illegible]

90. Air Pump. Describe Fig. [illegible] a bellows—*in the piston and cylinder* [illegible]

upon the orifice, and as the air cannot esc
same way it entered, it is forced out by th
the bellows. In the bottom of the cylinder
ure 43, there is a small hole, like a pin
drawing up the piston, the space below it
vacuum were it not that the air instantly
from the pipe, B, and the receiver, D, ar
space, as water runs into a syringe. A st
silk is tied firmly over the orifice in the
the cylinder on the inside, opening freel
when this air seeks entrance from below, b
downwards and preventing its return. T
should attempt to force down the cylind
below it would resist its descent; but a sm
made through the piston itself, and a valve
upper side opening upwards; so that on
the piston, the air below makes its way tl
valve and escapes into the open space at
raise the piston, and the air in the receiver
through a valve in the bottom of the cylind
upwards. The original air of the receiver
expanded equally through the receiver, th
and the connecting-pipe, we thrust down
and the portion of the air that is contained
inder is forced out through the piston.
raise the piston, and the remaining air of th
expands itself as before through the vac
depress the piston, and a second cylinder
is withdrawn. By continuing this process,
more and more the air of the receiver, ever
the piston leaving what remains more rar
fore. Still, on account of the elasticity of
remains in the cylinder will always di
through the whole vessel, so that we cann
a complete vacuum by the air-pump.

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process of exhausting a vessel. Can we produce a com
by the air-pump?

91. Several experiments will illustrate the great *pressure of the atmosphere*, when no longer balanced by an equal and opposite force. We shall find the receiver, when exhausted by the foregoing process, held firmly to the plate of the pump so that we cannot remove it until we have opened the screw, S, and admitted the air; then the downward force of the air being counterbalanced by an equal force from within, the vessel is easily taken off. The *MagdeburgHemispheres*, represented in figure 44, afford a striking illustration of the force of atmospheric pressure. When they have air within as well as without, they are easily, when joined, separated from each other; but let us now put them closely together and screw the ball thus formed upon the plate of the pump, exhaust the air, and close the stop-cock so as to prevent its return. We then unscrew the ball from the pump, and screw on the loose handle; the hemispheres are pressed so closely together that two men, taking hold by the opposite handles, can hardly pull them apart. Hemispheres four inches in diameter would be held together with a force equal to 188 pounds. Otto Guericke, of Magdeburg, in Germany, who invented the air pump and contrived this experiment, had a pair of hemispheres constructed, so large that sixteen horses, eight on each side, were unable to draw them apart. A pair only two feet in diameter, would require to separate them a force equal to 6785 pounds. If our bodies were not so penetrated by air, that the external pressure is counterbalanced by an equal force from

Fig. 44.

91. Give an example of the great pressure of the atmosphere. Describe the Magdeburg Hemispheres. What is said of those made by Otto Guericke? How much pressure does a middle sized man sustain? Why are we *not crushed*?

within, we should be crushed under the the atmosphere; for a middle sized man w tain a pressure of about 14 tons.

92. If we take a *square bottle*, fit a stop-c and exhaust the air, the pressure on the ou crush it into small fragments, with a loud It is prudent to throw a towel or handkerchi over it, to prevent injury from the fragr *square* bottle is preferred to a round one, bec a figure has less power of resistance. The experiment may be tried without an air p affords a pleasing illustration of the force pheric pressure. Cut out a circular piece grained sole leather, five or six inches in Through a hole in the center, draw a wax to serve as a handle. Soak the leather in v it is very soft and pliable; then, on applyi any smooth, clean surface, as that of a la slab of marble, or a table, it will adhere force, that we cannot lift it off; but whe upwards, the heavy body to which it is atta be lifted with it. We may, however, *sli* ease, because no forc on it to prevent its this direction, excep the adhesion of the Flies are said to asce of glass on this prir applying their broad f to the glass, which down by the pressure mosphere. When w sucker, and exhaust i mouth, the fluid rise

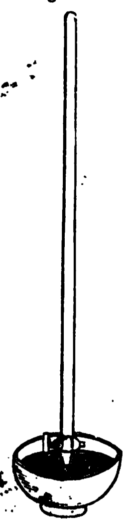
Fig. 45.

92. Describe the experiment with a square bottle. *stone experiment*. Why can we so easily *slide* the leath *flies ascend* smooth planes. How does the boy suck

ced up by the pressure of the atmosphere on its . When we draw in the breath, the lungs are ed like a pair of bellows. Thus the air runs e sucker into the lungs and forms a vacuum in ker. Immediately the pressure of the atmos- n the surface of the fluid, not being balanced ube, forces the fluid up the tube and thence mouth.

If we fill a phial with water, and, placing one n the mouth, invert it in a tumbler partly full r, the water will not run out of al, but will remain suspended, there being no air at the top of mn to balance the pressure that the mouth of the phial, the col- nnot descend. If, however, in- f the phial, we should employ a re than 33 feet long, on filling it erting it as was done with the e water would settle to about 33 d there it would rest; for the of the atmosphere is capable of ng a column of water only 33 h. Were it higher than this, it e more than a counterpoise for essure, and would overcome it k; and were it lower than that, l be overcome by that pressure, until it exactly balanced the the atmosphere. Instead of fill- pipe with water, we will attach a k to the open end, screw it on of the air-pump, and exhaust the air. We close the stop-cock, and removing the tube

Fig. 46.



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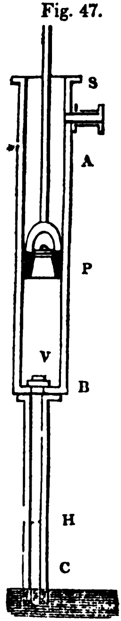
cribe the experiment with the phial. Also with a pipe more -three feet long. If we exhaust the pipe and open it under at happens?

from the pump, will place the lower end of in a bowl of water. On opening the stop-water will rush into the pipe, and rise to a same height as before, namely about 33 fee it will rest. In both cases, there is an emj or vacuum in the upper part of the pipe a column of water.

Fig. 47.



94. This experiment illustrates ciple of the *common pump*, of th and of the *barometer*. Let us how water is raised by the pum apparatus usually consists of two a larger, A B, above, and a smal below. The piston moves in tl pipe, and the smaller pipe desc the well. On the top of the latte it enters the former, is a valve, V upwards. Suppose the piston, P close to this valve. On raising from the lower pipe diffuses itse empty space below the piston, rarefied, and no longer balances sure of the atmosphere on the the well. Consequently, the forced up until the weight of t together with the weight of t air, restores the equilibrium. the piston being drawn up to rises to H; then the column, rarefied air in both pipes to counterbalance the weight c phere. On raising the pisto the water rises above H, but would not p the valve, V, by a single elevation of the

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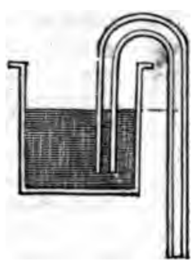
94. Explain the common pump from Fig. 47. Ho *the* atmosphere exert in raising the water?

therefore thrust down the piston to repeat the operation. The air between V and P is prevented from returning into the lower pipe, by the valve, V, which shuts downwards; but the enclosed air, when compressed by the descending piston, lifts a valve in the piston, as in the air-pump, and escapes above. On drawing up the piston a second time, suppose that the water rises into the upper pipe above the valve, V, then on depressing the piston again, this water, pressed on by the piston, lifts its valve, and gets above it. Finally, on drawing up the piston again, this same water is lifted up to the level of the spout, S, where it runs off. We exert just as much force in exhausting the air, as the pressure of the atmosphere exerts in raising the water. It requires, therefore, just as much force to raise a given quantity of water by the pump, as to draw it up in a bucket; and the only question is, which is the most convenient mode of applying the force.

95. The *Syphon* is a bent tube, having one leg longer than the other, as in figure 48. If we dip the shorter leg into water and suck out the air from the tube, the water will rise, pass over the bend, flow out at the open end, and continue to run until all the water in the vessel is drawn off. Here the pressure of the atmosphere on both mouths of the tube is the same; but in each arm, that pressure is resisted by the weight of the column of water above it, and more by the longer than by the shorter column. This is the same thing as though the pressure were less upon the outer

Fig. 48.



95. Describe the Syphon. Why does it draw off the liquid? State the uses of the Syphon. How high will it raise water?

than upon the inner mouth; and it is ‹
that if the water in a tube is pressed
more than the other, it will flow in the
which the pressure is greatest. The syp
in drawing off liquors; and the water in a
sometimes conveyed over hills on the prin
syphon. But we must remember
could not be raised by it more th
for when the bend is 33 feet abo
of the fountain, then the column
er arm balances the pressure of
phere at the mouth of the tube in tl
leaves no force to drive forward
into the descending arm.

Fig. 49.

96. The *Barometer* is an ins
measuring the pressure of the atm(
the atmosphere be conceived to
into perpendicular columns, the
measures the weight of one of tl
height of a column of quicksilve
takes to balance it. Quicksilver i
as heavy as water, and therefore a
much shorter than one of water, v
the weight of an atmospheric colu
will imply a column about $2\frac{1}{2}$ f
inches high, and it will be much
venient to experiment upon such
than upon one of water 33 feet
will therefore take a glass tube a
feet long, closed at one end and
other, fill it with quicksilver, and
finger firmly on the open mouth, v
sert this below the surface of the
small cistern, as represented in

96. Define the Barometer. Describe the mode of makir
At what height will the quicksilver rest? What is the
called?

On withdrawing the finger, the quicksilver in the tube will settle to the height of about thirty inches, where it will rest, being sustained by the pressure of the atmosphere on the surface of the fluid in the cistern, to which force its weight is exactly equal. The space above the quicksilver, is the best vacuum we are able to form. It is called the *Torricellian* vacuum, from Toricelli, an Italian philosopher, who first formed it. The weight of a column of atmospheric air is different in different states of weather, and its variations will be indicated by the rising and falling of the quicksilver in the barometer. Any increase of weight in the air will make the fluid rise; any diminution of weight will make it fall. Hence, these variations in the height of the barometic column, show us the comparative weight and pressure of the atmosphere at any given time. By applying to the upper part of the tube a scale divided into inches and tenths of an inch, we can read off the exact height of the quicksilver at any given time. Thus, the fluid, as represented in the figure, stands at 29.4 inches.

97. The barometer is one of the most useful and instructive of philosophical instruments. By observing it from time to time, we may find how its changes are connected with the changes of weather, and thus it frequently enables us to foretell such changes. If, for example, we should observe a sudden and extraordinary fall of the barometer, we should know that a high wind was near, possibly a violent gale. To seafaring men, the barometer is a most valuable instrument, since it enables them to foresee the approach of a gale, and provide against it. As a general fact, the rising of the barometer indicates *fair*, and its falling, *foul* weather.

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97. Explain the use of the barometer as a weather glass. What would a sudden and extraordinary fall indicate? What weather does its *rise*, and what its *fall* indicate?

98. The foregoing considerations relate to the weight and pressure of the atmosphere; but the air-pump also affords us interesting illustrations of the *elasticity* of air. We will fill a phial with water, and invert it in a tumbler partly filled with the same fluid. We will now place the tumbler and phial on the plate of the air-pump, and cover it with a receiver, and exhaust the air. Soon after we begin to work the pump, we shall see minute bubbles of air making their appearance in the water, which will rise and collect in a bubble at the top of the column. The bubble thus formed, will expand more and more as the exhaustion proceeds, until it expels the water, and occupies the whole interior of the phial. This will happen much sooner if we let in a bubble of air at first, and do not wait for it to be extricated from the water; but this extrication of air from the water, is itself an instructive part of the experiment, as it shows us that water contains a large quantity of air, held in combination with it by the pressure of the atmosphere on the surface, which pressure pervades all parts of the fluid alike. But on withdrawing this pressure gradually from the surface of the water, the particles of air imprisoned in the pores of the water, escape, and collect on the top. The bubble thus formed, will expand more and more as the pressure is still farther removed, until it drives down the water and fills the whole phial. If we turn the screw S of the pump (Fig. 43) and let in the air, the pressure on the surface of the water in the tumbler being res-

Fig. 50.

98. Describe Fig 50, and show how it illustrates the elasticity of air. What will porous bodies give out in an exhausted reciver? How will *warm* water be affected?

red, the water will be forced up the phial again, id the air will be reduced to its original bubble. If e place any porous substance, as a piece of brick, or crust of bread, in a tumbler, and fill the tumbler ith water, (attaching a small weight to the bread to ep it under) we shall see in like manner, an unex-cted amount of air extricated when we place it under e receiver, and remove the atmospheric pressure om it, so as to permit it to assume the elastic state. iquids boil at a much lower temperature than usual, hen the pressure of the atmosphere is removed from em. Thus, if we take a tumbler half full of water, more than blood warm, set it under the receiver, id exhaust the air, it will boil violently.

99. Air is the medium of *combustion*, of *respiration*, id of *sound*. If we place a lighted candle under the ceiver of an air-pump, and exhaust the air, the light ill immediately go out, showing that bodies cannot irn without the presence of air. Nor without this in animals breathe. A small bird placed beneath the ceiver, will cease to breathe as soon as the air is khausted. If a bell, also, is made to ring under a ceiver, the sound will grow fainter and fainter as ie air is withdrawn, and finally be scarcely heard at ll. The *buoyancy* of air, like that of water, enables to support light bodies. In a vacuum, the heaviest nd lightest bodies descend to the earth with the same elocity. If we suspend a guinea and a feather from ie top of a tall receiver, exhaust the air, and let them ll at the same instant, the feather will keep pace ith the guinea, and reach the plate of the pump at ie same instant.

100. THE CONDENSER. A piston and cylinder may e so contrived as to pump air into a vessel instead of

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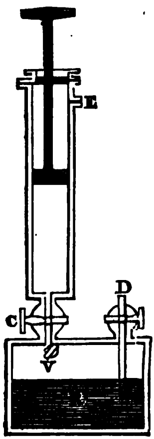
99. How may we show that air is essential to combustion? Also to fe? Also to sound? Describe the guinea and feather experiment.

pumping it out. Figure 51 represents a
syringe, screwed to a box partly filled w
When the piston is drawn up to the top, ab
fice E in the side, the air r
which on depressing the
driven forward into the bo
valve, V, which opens in
closes outwards, and prev
turn of the air. By repeat
the piston, more and more a
into the box, constantly
the pressure on the surf
water. D is a tube openi
sing by a stop cock, havin
end in the water. Wher
strongly condensed, on o
stop-cock, the water issu
tube with violence. *S*
Fountains are construct
principle. A great quan
bonic acid, or fixed air, is
a strong metallic vessel,
a solution of soda, and t

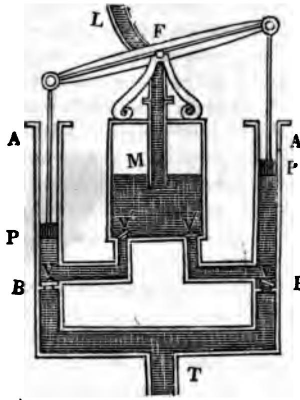
Fig. 51.



subjected to a powerful pressure. A tub
this vessel to the counter where the liqu
drawn, which issues with violence, as sc
is given to it, and foams, in consequeace
bonic acid expanding by the removal of tl
by which it had been confined. The con
ployed for this purpose, is called a *forcing*
differs from the condensing syringe, rep
figure 51, chiefly in being worked by a le
ed to the piston, instead of the naked hand

100. Describe the Condenser from Fig. 51. How is a
the box? Explain the principle of soda water fountains
forcing pump?

Fig. 52.



01. The *Fire Engine* throws water by means of forcing pumps, one on each side, which are work- by the fire-men. T represents the hose, or leath- pipe, which leads off to some well or cistern of ter, whence the supply is drawn. F is the work- beam, to each end of which is attached a piston ving in the cylinder A B. Suppose, at the com- ncement of the process, the left hand piston is rn close to the valve V; as it rises, the water fol- s it from the hose, lifting the valve V, and enter- P B below the piston. When the piston descends, orces the water through a valve into the air- sel, M. As the water is thrown in by successive cents of the piston, it rises in M, and condenses air of the vessel into a small space at the top. A ond hose, F, dips into the water, and terminates in farther end in a pipe, which the fireman directs

1. Describe the fire-engine from Fig. 52. Why is the air-vessel ? Use of air-springs and air beds.

upon any required point, sending the water in a tinual stream. The stream might indeed be pr ed directly by the action of the pistons, withou intervention of the compressed air in M; but in case it would go by jerks; whereas, the elastic the confined air acts as a uniform force, and the water flow out in a continual stream. *Air-sp* acting on the same principle, are sometimes att to coaches, and are said to operate well. *Beds* been filled by inflating them with air instead of ers, and have the advantage of being always ma

SEC. 2. *Of Steam and its Properties.*

102. Steam, or the elastic fluid which is pro by heating water, owes its mechanical efficacy power of suddenly acquiring by heat, a powerfu ticity, and then losing it as suddenly, by co the former case, expanding rapidly, and exp every thing else from the space it occupies; a the latter case, shrinking instantly to its origi mensions in the state of water, and thus forming cuum. By this means, an alternate motion is to a piston, which being communicated to mach supplies a force capable of performing every labor, and being easily endued with any requir gree of energy, is at once the most efficient an most manageable of all the forces of nature. if steam be admitted below the piston, in figu when its force accumulates sufficiently to ove the resistance of the piston, it raises it; and if i be let in above the piston, it depresses it. Wh piston rises, it may be made to turn a cranl round, and the other half when it falls, and t

102. To what two properties does steam owe its mechanica cy? To what is the motion first communicated, and how tra to machinery? Show how the piston is raised and depressed.

main wheel may be made to revolve, from which motion may be conveyed to all sorts of machinery. The degree of force which steam exerts, depends on the *temperature* and *density* conjointly. If we put a spoonful of water into a convenient vessel, as an oil-flask, and place it over the fire, the water will soon be turned into elastic vapor, which will drive out the air and fill the entire capacity of the vessel. As soon as this takes pla[illegible]e cork the flask and again set it over the fire. [illegible] steam will increase in elastic power, just as [illegible] of air would do, which is only at a moderate rate, and it might be heated red hot without exerting any violent force. If we now unstop the flask and fill it one third full of water, and again place it on the fire, and stop it close when it is boiling freely, then successive portions of water will be constantly passing into vapor, and, of course, the steam in the upper part of the vessel will be constantly growing more and more dense. It is important to remember, therefore, that when steam is heated by itself, and not in contact with water, its elasticity increases slowly, and never becomes very great; but when it is heated in a close vessel containing water, which makes to it constant additions of vapor, thus increasing its density, it rapidly acquires elastic force, and the faster the longer the heat is continued, so as shortly to reach an energy which nothing can resist. Such an accumulation of force sometimes takes place by accident in a steam boiler, and produces, as is well known, terrible explosions.

103. If the foregoing principles are well understood, it will be easy to learn the construction and operation of the *Steam Engine*. For the sake of simplicity, we will leave out numerous appendages which

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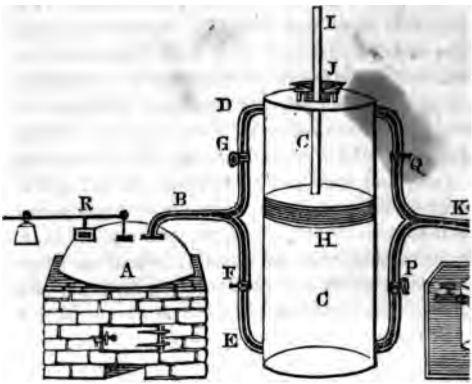
What does the degree of force depend? Experiment with a flask of steam with and without water.

usually accompany this apparatus, but are ı tial to the main principle. In figure 53, A ı

Fig. 53.



the *boiler*, C the *cylinder*, in which the piston L the *condenser*, and M the *air-pump*. B is *pipe*, branching into two arms, communic pectively with the top and bottom of the cyl K is the *eduction-pipe*, formed of the two which proceed from the top and bottom of der on the other side, and communicate be cylinder and the condenser, which is imm well or cistern of cold water. Each bra pipe has its own valve as F, G, P, Q, whi opened or closed as occasion requires. R valve, closed by a plate, which is held d weight attached to a lever, and sliding on to increase or diminish the force at pleasur

103. Describe Figure 53.

force of the steam exceeds this, it will lift the
e and escape, thus preventing the danger of ex-
ion.

04. Suppose, first, that all the valves are open,
that steam is issuing freely from the boiler. It is
y to see, that the steam would circulate freely
ugh all parts of the engine, expelling the air
ch would escape through the valve in the piston of
air-pump, and thus the interior spaces would be
filled with steam. This process is called *blowing*
it is heard when a steam-boat is about leaving
wharf. Next the valves, F and Q, are closed, G
P remaining open. The steam now pressing on
cylinder, forces it down, and the instant when it
ins to descend, the stop-cock O is opened, through
ch cold water meets the steam as it rushes from
cylinder and condenses it, leaving no force below
piston to oppose its descent. Lastly, G and P
g closed, F and Q are opened, the steam flows
rom the boiler below the piston, and rushes from
ve into the condenser, by which means the piston
forced up again with the same power as that by
ch it descended. Meanwhile, the air-pump is
ring, and removing the water and air from the con-
ser, and pouring the water into a reservoir, whence
conveyed to the boiler to renew the same circuit.

05. In *High Pressure* engines, the steam is not
densed, but discharges itself directly into the at-
phere. The *puffing* heard in locomotives, arises
this cause. High pressure engines are those in
ch steam of great density, and high elastic power,
sed. By this means, a more concentrated force
roduced, and the engine may be smaller and more

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4. Show how the engine is set a going, and kept at work.
5. What becomes of the steam in high pressure engines? Whence s the puffing heard in locomotives? What are high pressure en- s? What are *their* advantages over low pressure engines?

compact; but unless it is made proportionally s er, it is more liable to explode, and when it gives it explodes with great violence.

CHAPTER V.

METEOROLOGY.

GENERAL OBJECTS OF THE SCIENCE—EXTENT, DENSITY AND PERATURE OF THE ATMOSPHERE—ITS RELATIONS TO WA RELATIONS TO HEAT—RELATIONS TO FIERY METEORS.

106. METEOROLOGY *is that branch of Natural losophy which treats of the Atmosphere.* In P matics, we learn the properties of elastic fluid general, on a small scale, and by experiment ra than by observation; but in Meteorology, we ex our views to one of the great departments of na and we reason, from the known properties of air vapor, upon the phenomena and laws of the entire of the air, or the atmosphere. Meteorology l us to consider, first, the *description* of the atmosp itself, including its extent, condition at diff heights, and the several elements that compose secondly, the relations of the atmosphere to *wate* cluding the manner in which vapor is raised into atmosphere, the mode in which it exists there, the various ways in which it is precipitated in the of dew, fog, clouds, rain, snow and hail; thirdly, relations of the atmosphere to *heat*, embracing motions of the atmosphere as exhibited on a s scale, in artificial draughts and ventilation; an a large scale, in winds, hurricanes, and tornad

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106. Define Meteorology. How distinguished from Pneuma What different subjects does Meteorology lead us to consider?

finally, in the relations of the atmosphere to *fiery meteors*, as thunder and lightning, aurora borealis, and shooting stars.

SEC. 1. *Of the Extent, Density, and Temperature of the Atmosphere.*

107. The atmosphere is a thin transparent veil, enveloping the earth, and extending to an uncertain height, but probably not less than one hundred miles above it. Since air is elastic, and the lower portions next to the earth sustain the weight of the whole body of air above them, they are compressed by the load, as air would be under any other weight. As we ascend above the earth, the air grows thinner and thinner very fast, so that if we could rise to the height of seven miles in a balloon, we should find the air four times as rare there as at the surface of the earth. The air is, indeed, much more rare on the tops of high mountains than at the level of the sea; and at a height much greater than that of the highest mountains on the globe, man could not breathe, nor birds fly. The upper regions of the atmosphere are also very *cold*. As we ascend high mountains, even in the torrid zone, the cold increases, until we finally reach a point where water freezes. This is called the *term of congelation*. At the equator, it is about three miles high; but in the latitude of 40, it is less than two miles, and in the latitude of 80, it is only one hundred and twenty feet high. Above the term of congelation, the cold continues to increase till it becomes exceedingly intense. The clouds generally float below the term of congelation. Mountains, when very high, are usually covered with snow all the year

107. Give a general description of the atmosphere, as to its height—density at different heights—cold of the upper regions—what is the term of *congelation*? How high at the equator? At 40° and 80°?

ound. even in the warmest countries, merely bec
.hey are above this boundary.

SEC. 2. *Of the Relations of the Atmosphe Water.*

108. Besides common air, the atmosphere al contains more or less watery vapor, a minute po of fixed air, or carbonic acid, and various exhalat which are generally too subtile to be collected separate state. By the heat of the sun, the w on the surface of the earth are daily sending int atmosphere vast quantities of watery vapor, w rises not only from seas and lakes, but even from land, wherever there is any moisture. The vapor raised, either mixes with the air and remains in ble, or it rises to the higher and colder regions, is condensed into clouds. Sometimes accid causes operate to cool it near the surface of the and then it forms fogs. It returns to the earth i forms of dew, and rain, and snow, and hail.

109. *Dew* does not fall from the sky, but is d ed from the air on cold surfaces, just as the moisture is, which we observe on a tumbler water in a sultry day. Here, the air coming tact with a surface colder than itself, has a p the invisible vapor contained in it conden water. In the same manner, on clear and sti which are peculiarly favorable to the forn dew, the ground becomes colder than the a latter circulating over it, deposits on it things near it, a portion of its moisture. not form on all substances alike that are

108. What other elastic fluids besides air does the tain? Whence is the watery vapor derived? What

109. How is dew formed? Does dew form on all s *What* receive the most? What receive none?

posed to it. Some substances on the surface of the earth, are found to grow colder than others, and these receive the greatest deposit of dew. Deep water, as that of the ocean, does not grow at all colder in a single night, and therefore receives no dew; and the naked skins of animals, being warmer than the air, receive none; although the moisture which is constantly exhaled from the animal system itself, as soon as it comes into contact with the colder air that surrounds the person, may be condensed, and moisten the skin or the clothes in such a way as to give the appearance of dew. In this manner, also, frost (which is nothing more than frozen dew,) collects, in cold weather, on the bodies of domestic animals. By a beautiful provision of Providence, dew is always guided with a frugal hand to those objects which are most benefited by it. Green vegetables receive much more than naked sand equally exposed, and none is squandered on the ocean.

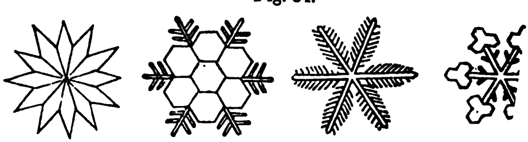
110. *Rain* is formed in the atmosphere at some distance above the earth, where warm air becomes cooled. If it is only cooled a few degrees, the moisture may merely be condensed into cloud; but if the cooling is greater, rain may result; and when a hot portion of air, containing, as such air does, a great quantity of watery vapor in the invisible state, is suddenly cooled by any cause, the rain is more abundant, or even violent. In such cases, it may have been cooled by meeting with a portion of colder air, as when a warm south-westerly wind meets a cold northwester, or by rising into the upper regions near the term of congelation. In some parts of the earth, as in Egypt, and in a part of Chili and Peru, it seldom or never rains, for there the winds usually blow

110. Where is rain formed, and how? When is the precipitation in the form of cloud? When of rain? When is the rain violent? In

steadily in one direction, and encounter none of thos mixtures with colder air which form rain. In som other countries, as the north-eastern part of Sout America, the rains are excessive; and in others, a most tropical countries, the rains are periodical, bein very copious at particular periods called the rain seasons, while little or none falls during the other part of the year.

111. *Snow* is formed from vapor crystallized b cold instead of uniting in drops. By this means it i converted into a light downy substance, which fall gently upon the earth, and forms a covering that con fines the heat of the earth, and furnishes an admirabl defence of the vegetable kingdom, during winter, in se vere climates. In cold climates, flakes of snow consis of regular crystals, presenting many curious figures which, when closely inspected, appear very beauti ful. Nearly a hundred distinct forms of these crystal have been particularly described by voyagers in th polar seas, a specimen of which, as they appear und the magnifier, are exhibited in the following diagrar

Fig. 54.



When a body of hot air becomes suddenly intensely cooled, the watery vapor is frozer forms *hail*. The most violent hailstorms are f by whirlwinds, which carry up bodies of hot beyond the term of congelation, where the d

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what different ways is the hot air cooled? Where does it n Why? Where are the rains excessive? Where periodic 111. Snow, how formed? What purpose does it serve manner does it crystalize, and in how many different form is hail formed? How are the most violent hail storms forme rain are frozen into hailstones, and these being sustained for sometime by the upward force of the whirlwind, accumulate occasionally to a very large size. Hailstorms are chiefly confined to the temperate zones, and seldom occur either in the torrid or the frigid zone. In the equatorial regions, the term of congelation is so high, that the hot air of the surface, if raised by a whirlwind, would seldom rise beyond it; and in the polar regions, the air does not become so hot as is required to form a hailstorm.

Sec. 3. *Of the Relations of the Atmosphere to Heat.*

112. It is chiefly by the agency of heat, that air is put in motion. If a portion of air is heated more than the surrounding portions, it becomes lighter, rises, and the surrounding air flows in to restore the equilibrium; or if one part be cooled more than another, it contracts in volume, becomes heavier, and flows off on all sides until the equilibrium is restored. Thus the air is set in motion by every change of temperature; and as such changes are constantly taking place, in greater or less degrees, the atmosphere is seldom at rest at any one place, and never throughout any great extent. The most familiar example we have of the effects of heat in setting air in motion, is in the *draught of a chimney*. When we kindle a fire in a fire-place, or stove, it rarefies the air of the chimney, and the denser air from without rushes in to supply the equilibrium, carrying the smoke along with it. Smoke, when cooled, is heavier than air, and tends to descend, and does

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hail stones acquire so large a size? To what regions are hail storms chiefly confined? Why do they not occur in the torrid and frigid zones?

112. By what agent is air put in motion? Describe the process. How is the draught of a chimney caused? Why does smoke ascend?

descend unless borne up by a current of heated air. hot current of air in a chimney, is cooled much m rapidly when the materials of the chimney are da than when they are dry, and therefore it will cool m faster in a wet than in a dry atmosphere. Hen chimneys are apt to smoke in wet weather. It is sential to a good draught, that the inside of a chim should be smooth, for air meets with great resista in passing over rough surfaces. Burning a chim improves the draught, principally by lessening the fr tion occasioned by the soot. In stoves for burni anthracite coal, it is important to the draught, that air should get into the chimney except what g through the fire. On account of the great resistar which a thick mass of anthracite opposes to air, t will not work its way through the coal if it can into the chimney by any easier route. Hence pipes which conduct the heated air from a stove the chimney, should be close, especially the jo where the pipe enters the chimney; and care sho be taken, that there should be no open fire-place, other means of communication, between the exter air and the flue with which the stove is connected.

113. It is important to health, that the apartments a dwelling-house should be well *ventilated*. This is pecially the case with crowded rooms, such as chur es and school-houses. Of the method of ventilati churches, a beautiful specimen is afforded in the C ter Church, in New Haven. In the middle of ceiling, over the body of the church, is an openi through the plastering, which presents to the e nothing but a large circular ornament in stucco. O this, in the garret of the building, a circular enclos

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Why do chimneys smoke in wet weather? Why should a chim be smooth? Why does burning a chimney improve the draug What precautions are necessary in burning anthracite coal, in orde secure a good draught?

of wood is constructed, on the top of which is built a large wooden chimney, leading off, at a small rise, to the end of the building, where it enters the steeple. An upper window of the steeple being open, in warm weather, the current sets upward from the church into the chimney, and thence into the tower, and completely ventilates the apartment below. A door, so hung as to be easily raised or lowered by a string, leading to a convenient place at the entrance of the church, can be opened or closed at pleasure. In cold weather, it will generally be found expedient to keep it closed, to cut off cold air, opening it only occasionally. A school-house may easily be ventilated by a similar contrivance connected with a belfry over the center, as is done in several school-houses recently built in New England.

114. Nature, however, produces movements of the atmosphere on a far grander scale, in the form of *Winds*. These are exhibited in the various forms of breezes, high winds, hurricanes, gales, and tornadoes; varieties depending chiefly on the different velocities with which the wind blows. A velocity of twelve miles an hour, makes a strong breeze; sixty miles, a high wind; one hundred miles, a hurricane. In some extreme cases, the velocity has been estimated as high as three hundred miles an hour. The force of the wind is proportioned to the square of the velocity; a speed ten times as great, increases the force a hundred times. Hence, the power of violent gales is irresistible. Air, when set in motion, either on a small or on a great scale, has a strong tendency to a whirling motion, and seldom moves forward in a straight line. The great gales of the ocean, and the small

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113. Ventilation in what cases is it important? How effected in churches—how in school-houses?

114. Specify the different varieties of winds. State the velocity of a breeze—of a high *wind*—of a hurricane. How is the force of a wind *proportioned to the velocity?* Tendency of air to a whirling motion.

tornadoes of the land, often, if not always, exhibit more or less of a rotary motion, and sometimes appear to spin like a top around a perpendicular axis, at the same time that they advance forward in some great circuit.

115. METEOROLOGICAL INSTRUMENTS. The principal of these are the Thermometer, the Barometer, and the Rain Gage. The principle, construction, and uses of the *Barometer*, have already been pointed out, (Arts. 96 and 97.) Since it informs us of the changes that take place in the weight and pressure of the atmosphere, at any given place, on which depend most of the changes of weather, it becomes of great aid in the study of Meteorology, and has, in fact, led to the knowledge of most of the laws of atmospheric phenomena hitherto established. We should, in purchasing, be careful to select an instrument of good workmanship, for no other is worthy of confidence. We should suspend it in some place where there is a free circulation of air—as in an open hall, having an outside door—and we should take the exact height of the mercury at the times directed below for recording the thermometrical observations. In case the barometer is falling or rising with unusual rapidity, observations should be recorded every hour, or even oftener, as such observations afford valuable means of comparison of the states of the atmosphere at different places.

116. The *Thermometer* is an instrument used for measuring variations of temperature by its effects on the height of a column of fluid. As heat expands and cold contracts all bodies, the amount of expansion or contraction in any given case, is made a criterion of

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115. What are the three leading meteorological instruments? Great value of the barometer. Rules for selecting a barometer and for observing.

116. For what is the thermometer used? What shows the change

hange of temperature. Fahrenheit's thermome-
ıe one in common use, consists of a small glass
called the stem, with a bulb at one end, and a
at the side. The bulb and a certain part of the
ıre filled with mercury. The scale is divided
egrees and aliquot parts of a degree. If we dip
ermometer into boiling water, the mercury will
d and rise in the stem to a certain height, and
remain stationary. We will, therefore, mark
oint on the stem, and then transfer the thermom-
a vessel where water is freezing. The mer-
now descends to a certain level, and remains
stationary, as before. We mark this point, and
ıs obtain the two most important fixed points on
ale, namely, the freezing and boiling points of

We will now apply the scale, and transfer
marks from the stem to the scale, and divide the
the scale between them into 180 equal parts,
uing the same divisions below the freezing point
rees, where we make the zero point, and there
the graduation from 0 to 32, the *freezing* point,
on 180 degrees more, to 212, the *boiling* point.
best times for making and recording observa-
are when the mercury is lowest, which occurs
sun-rise, and when it is highest, which is near
'clock in winter, and three in summer. The
these observations, divided by two, gives the
e, or *mean*, for the twenty-four hours; the sum
daily means for the days of a month, give the
for that month; and the monthly averages, divi-
twelve, give the annual mean. By such ob-
ons, any one may determine the temperature of
ıce where he resides.

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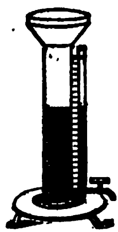
erature? Describe Fahrenheit's thermometer. How do we
ı the boiling and freezing points of water? Into how many
is the space between them divided? Where is the zero point,
what degrees are the freezing and boiling points? How to find
, monthly, and annual means?

117. The climate of the United Sta
riable, and the annual range of the tl
greater than in most other countries.
140°, extending from 40° below zero, (t
—40°,) to 100° above. In the souther
England, the mercury seldom rises al
descends but a few times in the wint
From 70° to 80° is a moderate summer h
the equatorial regions of the earth a
hotter than places either north or soutl
seen that the temperature of a place de
ous other circumstances as well as o
(Arts. 82 and 107.)

118. The *Rain Gage* is
employed for ascertaining
water that falls from the sk
forms of rain, snow, and h
plest form is a tall tin cylin
nel-shaped top, having a g
tube communicating with
rising on the side. The v
at the same level in the tı
cylinder, and the divisions
be sueh as to indicate mir
inch, and thus determine the depth of ra
the area of the funnel, suppose a squa
the rain is over, the water may be rem
of the stop-cock, and the apparatus wi
a new observation. It is useful to kn
of rain that falls annually at any given
in reference to a knowledge of the cl
for many practical purposes to which w

Fig. 55



117. What is said of the climate of the United St
annual range of the thermometer? In New En
range? What is a moderate summer heat?

118. What is the Rain Gage? Explain the si
to find the amount of rain fallen? Why is it
amount of rain that falls?

eeding canals, turning machinery, [illegible] irriga-

. *Of the Relations of the Atmosphere to Fiery*

The luminous phenomena which go under the ame of "fiery meteors," are Thunder Storms, Borealis, and Shooting Stars. Sudden and howers of rain, in hot weather, are usually nied by thunder and lightning. The light- wing to the sudden discharge of electricity, hunder is ascribed to the rushing together of site portions of air, that are divided by the f the electric current. The snapping of a ends on the same principle as a clap of thun- e lash divides the air, and the forcible meet- e opposite parts to restore the equilibrium, the sound. Whenever hot vapor is rapidly d, a great amount of electricity is evolved. umulates in the cloud, until it acquires force leap from that to some other cloud, or to the to some object near it, and thus the explo- s place.

'he *Aurora Borealis, or Northern Lights*, are arkable in the polar regions, and are seldom seen in the torrid zone. They sometimes nerely the appearance of a twilight in the metimes they shoot up in streamers, or ex- ckering light, called *Merry Dancers*; some- y span the sky with luminous arches, or d more rarely they form a circle with stream-

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t are the three varieties of fiery meteors? How is light- ed? To what is thunder ascribed? How explained by of a whip? Origin of the electricity of thunder storms? n explosion take place?

a Borealis, where most remarkable? Specify the several

ers ra[illegible] on all sides of it, a little so
zenith, called the corona. The aurora t
equally prevale[illegible] all ages, but has part
of visitation, a[illegible] intervals of many
more prevalent in the autumnal months t
parts of the year, and usually is most s
earlier parts of the night, frequently kin
great splendor about 11 o'clock. From
inclusive, was a remarkable period of a
cause of this phenomenon is not known
erroneously ascribed to electricity, or m
it is probably derived from matter found
etary spaces, with which the earth falls
revolving around the sun.

121. *Shooting Stars* are fire-balls wh
the sky, appearing suddenly, moving w
velocity, and as suddenly disappearin
leaving after them a long train of ligh
occasionally observed in great numbers,
are called *Meteoric Showers*. Two peric
are particularly remarkable for these dis
the 9th or 10th of August, and the 1
November. The most celebrated of t
occurred on the morning of the 13th
1833, when meteors of various sizes
of splendor, descended with such
to give the impression that the stars w
from the firmament. The exhibition
equally brilliant in all parts of North
lasted from about 11 o'clock in the evenin
This phenomenon began to appear in
the world, as early as November, 1830,

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varieties. Is it equally prevalent in all ages? Wh
ble period? Is its cause known? To what has it b
what part of the year is it most frequent?

121. What are shooting stars? What two peri
remarkable for their occurrence? When did the

ır at the same period of the year, every year, l, when it reached its greatest height. It ated on a smaller scale, every year, until ;e which time nothing remarkable has been at this period. The meteoric shower of ill (1843) continues. Meteoric showers ap- rise from portions of a body resembling a hich revolves about the sun, and sometimes near the earth that portions of it are attracted the earth, and are set on fire as they pass ıe atmosphere.

CHAPTER VI.

ACOUSTICS.

MOTION—VELOCITY OF SOUND—REFLEXION OF SOUND—ICAL SOUNDS—ACOUSTIC TUBES—STETHOSCOPE.

.COUSTICS (a term derived from a Greek word ;nifies *to hear*,) *is that branch of Natural Phi- hich treats of sound.* Sound is produced by :ions of the particles of a sounding body. brations are communicated to the air, and the ear, which is furnished with a curious specially adapted to receive them and con- . to the brain, and thus is excited the sen- hearing. Vibration consists in a motion ırticles of a body, *backwards and forwards,* n exceedingly minute space. The particles :ontact with the body, receive a correspond- n, each particle impels one before it, and re-

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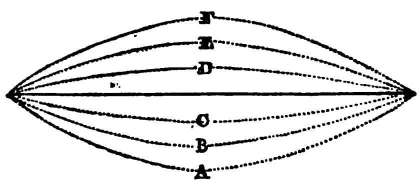
r? Describe this shower. Whence do meteoric showers

ıe Acoustics. How is sound produced? In what does ısist? *Does it imply a progressive motion?* What bo-

bounds; and thus the motion is propagated from particle to particle, from the sounding body to the ear. Such a vibratory motion of the medium, does not imply any current or progressive motion in the medium itself, but each particle recovers its original situation when the impulse that produced its vibration ceases. Elastic bodies being most susceptible of this vibratory motion, are those which are usually concerned in the production of sound. Such are thin pieces of board, as in the violin; a steel spring, as in the Jewsharp; a glass vessel, and cords closely stretched; or a column of confined air, as in wind instruments. If we stretch a fine string between two fixed points, and draw it out of a straight line to A, and then let it go, it will proceed to nearly the same distance on the other side, to

Fig. 56.



E, whence it will return to B, and thus continue to vibrate through smaller and smaller spaces, until it comes to a state of rest. When we throw a stone upon a smooth surface of water, a circle is raised immediately around the stone; that raises another circle next to it, and this another beyond it, and thus the original impulse is transmitted on every side. This example may give some idea of the manner in which sound is propagated through the air in all directions from the sounding body.

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dies are most susceptible of vibration? Give examples. Describe Fig. 56. What takes place when a stone is thrown on water?

23. Although air is the usual medium of sound, it is not the only medium. Solids and liquids, n they form a direct communication between the ıding body and the ear, conduct sound far better ι air. When a tea-kettle is near boiling, if we y one end of an iron poker to the kettle, and put other end to the ear, we may perceive when the er begins to boil, long before it gives the usual s. If we attach a string to the head of a fire-shovel, winding the ends around the fore fingers of both ds, apply them to the ears, and then ding the shovel nst an andiron, or any similar object, a sound be heard like that of a heavy bell. The ticking watch may be heard at the remote end of a long , or beam, when the ear is applied to the other ; and if the watch is let down into water, its beats distinctly heard by an ear placed at the surface. ell struck beneath the water of a lake, has been d at the distance of nine miles. Air is a better luctor of sound when moist than when dry. Thus, hear a distant bell or a water-fall with unusual nctness just before a rain, and better by night than lay. Air conducts sound better when condensed, worse when rarefied. On the tops of some of the ι mountains of the Alps, where the air is much fied, the sound of a pistol is like that of a pop-gun.

24. The *velocity* of sound in air is 1130 feet in a nd, or a little more than a mile in five seconds. this principle, we may estimate the distance of a ıder cloud, by the interval between the flash and report. For example, an interval of five seconds, s $1130 \times 5 = 5650$ feet, or a little more than a ι. A feeble sound moves just as fast as a loud

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. Is air the only medium of sound? Conducting power of solids quids? Experiment with a tea-kettle—with a fire-shovel—with ch. Conducting power of moist air?—Of rarefied air?

. **Velocity of sound. How to estimate the distance of a thunder** one. Its velocity is not altered by a high wind in a direction at right angles to the course of the wind; but in the same direction, the comparatively small velocity of the wind is to be added, and in the opposite direction to be subtracted. In water, the velocity of sound is about four times as great as in air, being 4709 feet per second; and in cast iron its velocity is more than ten times as great as in air, being no less than 11,895 feet per second.

125. Sound is capable of being *reflected*, and is thus sometimes returned to the ear, forming an *echo*. Thus, the sound of the human voice is sometimes returned to the speaker, or other persons near him, in a repetition usually somewhat feebler than the original sound; but it may be louder than that, if several reflected waves are unitedly conveyed to the ear. When one stands in the centre of a hollow sphere or dome, numerous waves being reflected from the concave surface so as to meet in the centre, a sound originally feeble becomes so augmented as to be astounding. A cannon discharged among hills or mountains, reverberates in consequence of the repeated reflexions of the sound.

126. A sound becomes *musical* when the vibrations are performed with a certain degree of frequency. The slow flapping of the wings of a domestic fowl has nothing musical; but the rapid vibration of the wings of a humming bird, produces a pleasant note. The slow falling of trees before a high wind, is attended with a disagreeable crash; the rapid prostration of the trees of a forest by a tornado, with a sublime roar. A string stretched between two points, and made to

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cloud? Velocity of a *feeble* sound—effect of a high wind? Velocity of sound in water?

125. Echo, how produced—when louder than the original sound? Effect of a dome—of a cannon among hills?

126. How a sound becomes musical?—examples in the wings of birds—in falling trees—in a vibrating string. How does increasing the

; very slowly, has nothing musical; but when
ision is increased, and the vibrations quickened,
ote grows melodious. The strings of a violin
ifferent sounds in consequence of affording vi-
ns more or less rapid. The larger strings, hav-
ower vibrations, afford graver notes. The screws
: us to alter the degree of tension, and thus to
se or diminish the number of vibrations at plea-
and by applying the fingers to the strings, we
orten them more or less, producing sounds more
; acute, by increasing the number of vibrations
iven time. In wind instruments, as the flute,
orating body which produces the musical tone is
lumn of air included within. This, by the im-
given by the mouth, is made to vibrate with the
ite frequency, which is varied by opening or
g the stops with the fingers. The shorter the
n, the more rapid is the vibration, and the more
the sound; and the length of the vibrating col-
; determined by the place of the stop that is open-
; higher stops giving sharper sounds because the
ng columns are shorter. The pipes of an organ
on a similar principle, the wind being supplied
ellows instead of the breath. In certain instru-
, as the clarinet and the hautboy, the vibrations
st communicated from the lips of the performer
eed, and from that to the column of air.

'. Sounds differing from each other by certain
als, constitute musical *notes*. The singing of
affords sweet sounds but no music, being uttered
uously and not at intervals. Man only, among
ls, has the power of uttering sounds in this man-

, the size, or the length of the string, affect the pitch? Ex-
n the violin. What produces the musical tone in wind instru-
Why does opening or closing the stops, alter the pitch?
the use of a reed.
What sounds constitute musical notes? Why is not the sing-
irds *music?* *Why is* man alone capable of uttering musical

ner; and his voice alone, therefore, is endued wi the power of music. . Music becomes a branch mathematical science, in consequence of the relati between musical notes, and the *number of vibratio* that produce them respectively. Although we cann say that one sound is larger than another, yet we ca say that the vibrations necessary to produce one sour are twice or thrice, or any number of times, more fr quent than those of another; and the number of vibr tions necessary to produce one note has a fixed rat to the number which produces another note. Thu if we diminish the length of a musical string one hal we double the number of vibrations in a given tim and it gives a sound eight notes higher in the sca than that given by the whole string, and is called octave. Hence, these sounds are said to be to eac other in the ratio of 2 to 1, because this is the ratio the numbers of vibrations which produce them. succession of single musical sounds constitute *melod* the combination of such sounds, at proper interval forms *chords;* and a succession of chords, produc *harmony.* Two notes formed by an equal number vibrations in a given time, and of course, giving th same sound, are said to be in *unison.* The relati between a note and its octave is, next after that of th unison, the most perfect in nature; and when the tw notes are sounded at the same time, they almost en tirely unite. Chords are produced by frequent *coinc dences of vibration,* while in discords such coinc dences are more rare. Thus, in the unison, the v brations are exactly coincident; in the octave, the tw coincide at the end of every vibration of the long string, the shorter meanwhile performing just tw vibrations; but in the second, the vibrations of the tw

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sounds? How does music become a branch of mathematical science Example in a musical string. Define melody, chords, harmony, un son. How are chords produced? How discords?

rings coincide only after eight of one string and nine
: the other, and the result is a harsh discord.

128. When an impulse is given to air contained in n open tube, the vibrations coalesce, and are propa-ated farther than when similar impulses are made n the open air. Hence the increase of sound effect-d by horns and trumpets, and especially by the speak-ng trumpet. Alexander the Great is said to have ad a horn, by means of which he could give orders his whole army at once. *Acoustic Tubes* are em-oyed for communicating between different parts of large establishment, as a hotel, or manufactory, by e aid of which, whatever is spoken at one extremity is ard distinctly at the other, however remote. They usually made of tin, being trumpet-shaped at each d. They act on the same principle as the speaking mpet. The *Stethoscope* is an instrument used by ysicians, to detect and examine diseases of the lungs d the heart. It consists of a small pipe of wood or ry with a funnel-shaped mouth, one of which is ap-ed firmly to the part affected and the other to the r. By this means the processes that are going on the organs of respiration, and in the large blood ssels about the heart, may be distinctly heard.

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28. Explain the effect of horns and trumpets. Use of Acoustic bes. how made? Explain the construction and use of the Stetho-pe.

CHAPTER VII.

ELECTRICITY.*

DEFINITIONS—CONDUCTORS AND NON-CONDUCTORS—A AND REPULSIONS—ELECTRICAL MACHINES—LEYDEN TRICAL LIGHT AND HEAT—THUNDER STORMS—LIGH —EFFECTS OF ELECTRICITY ON ANIMALS.

129. More than two thousand years a phrastus, a Greek naturalist, wrote of a sub call amber, which, when rubbed, has the p attracting light bodies. The Greek name was *electron*, (ηλεκτρον,) whence the scienc nominated ELECTRICITY. The inconsideral ment mentioned by Theophrastus, was neai the ancients knew of this mysterious agei two or three centuries past, new properties successively discovered, and new modes o lating it devised, until it has become one o important and interesting departments of n ence. It is common to call this power, v is, the electric *fluid*, although it is of too nature for us to show it, as we do air, and it possesses the properties of ordinary matte it is more like an elastic fluid of extreme r like any thing else we are acquainted with venient to denominate it a fluid, although we little of its nature.

130. Some bodies permit the electric flu freely through them, and are hence called c others hardly permit it to pass through them

*The experiments in this chapter are so simple, and require ratus, that it is hoped the learner will generally have the adv nessing them, which will add much more than mere descri provement and gratification.

129. Explain the name electricity. What did the anci this science? Its progress within two hundred years? tricity called a fluid?

130. Define conductors and non-conductors. Give

erefore called *non-conductors.* Metals are the ›nductors ; next, water and all moist substances ; xt, the bodies of animals. Glass, resinous subs, as amber, varnish, and sealing wax ; air, silk, cotton, hair, and feathers, are *non-conductors.* , stones, and earth, hold an intermediate place : ıre bad conductors when dry, but much better moist ; and air itself has its non-conducting greatly impaired by the presence of moisture. icity is *excited* by friction. If I rub the side of glass tumbler, or a lamp chimney, on my coat , the electricity excited will manifest itself by ing such light substances as bits of paper, cotdown. A stick of sealing-wax, when rubbed, ts similar effects. When an electrified body is 'ted by non-conductors so that its electricity cancape, it is said to be *insulated.* Thus, a lock of suspended by a silk thread is insulated, because ctricity be imparted to the cotton, it remains, it cannot make its escape either through the , or through the air, both being non-conductors. ss ball supported by a pillar of glass is insulated ; ıen supported on a pillar of iron or any other it is *uninsulated,* since the electricity does not ı in the ball but readily makes its escape through etallic support. By knowing how to avail ourof the conducting properties of some substances, e non-conducting properties of other substances, n either confine, or convey off the electric fluid ısure.

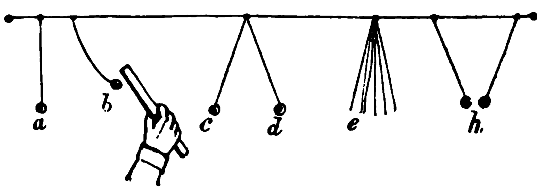
. There are a number of different classes of mena which electricity exhibits ; as attraction pulsion—heat and light—shocks of the animal ı—and mechanical violence. These will suc-

How is conducting power affected by moisture ? How is elecxcited ? When is a body insulated ? Give examples of incessively claim our attention; but as the properties of electricity were first discovered by experiment, so it is by experiments, chiefly, that they are still to be learned. We will therefore describe first, a few such experiments as every one may perform for himself, and afterwards such as require the aid of an electrical machine.

SEC. 1. *Of electrical Attractions and Repulsions.*

132. For a few simple experiments, we will stretch a wire horizontally between the opposite walls of a room, or between any two convenient points, as represented in figure 57. This will afford a convenient support

Fig. 57.



for *electroscopes*, as those contrivances are called, which are used for detecting the presence and examining the properties of electricity. A downy feather, a lock of cotton, or pithballs,* are severally convenient substances for electroscopes. To one of these, say a pithball, we will tie a fine linen thread, about nine inches long, and suspend it from the wire, as at *a*. By slightly wetting the thumb and finger and drawing the

*The pith of elder, of corn stalk, or of dry stalks of the artichoke, is suitable for this purpose.

131. What different classes of phenomena does electricity exhibit? Use of experiments.
132. Describe the apparatus in Fig. 57. How is the tube excited?

ıd through them, it becomes a good conductor and electroscope is therefore uninsulated. We will take a thick glass tube and rub it with a piece of (or a dry silk handkerchief,) by which means the will be excited, and on approaching it towards lectroscope, the pith-ball will be attracted towards at *b*, and may be led in any direction by shifting osition of the tube; or if the tube be brought r, the ball will stick fast to it. We will next nd two other balls, *c* and *d*, by silk threads, in h case they will be insulated. If we now ap- h the excited tube, the balls will first be attracted but as soon as they touch it, they will fly off, and ube when again brought towards them will no r attract but will repel them, and they will mutu- epel each other as in the figure; and if the lock reads, *e*, be electrified, they will also repel each . A stick of sealing wax excited and applied to lectroscopes will produce similar effects. But if rst electrify the ball with glass and then bring it the sealing wax, previously excited, it will not the ball, as the excited tube does, but will first t it as though it were unelectrified, and then re- ; and now the excited glass tube will attract it. e it appears that the glass and the sealing wax, excited, produce opposite effects: what one at- the other repels. Each repels its own, but at- the opposite. Glass repels a body electrified elf, but attracts a body electrified by sealing wax; ealing wax repels a body electrified by itself, but ts a body electrified by glass. In the figure, *h* sents two balls differently electrified, one by glass ne other by sealing wax, and therefore attracting other. This fact has led to the conclusion, that

when applied to the uninsulated ball—to the insulated balls to ads. Describe the effects when sealing wax is used when s are differently electrified. What are the two kinds of electricity?

there are *two kinds of electricity;* one excited by g
and a number of bodies of the same class, callec
vitreous electricity, and the other excited by se
wax and other bodies equally numerous, of the s
class with it, called the *resinous* electricity. Vit
electricity is sometimes called *positive*, and resi
electricity *negative*.

133. The foregoing cases of electrical attrac
and repulsions, constitute important laws of elec
action, and are to be treasured up in the memo
the following propositions:

First. An electrified body *attracts* all unelect
matter.

Secondly. Bodies electrified similarly, that is,
positively or both negatively, *repel* each other.

Thirdly. Bodies electrified differently, that is
positively and the other negatively, *attract* each c

Fourthly. The force of attraction or repulsion
versely as the square of the distance; that is, whe
balls are electrified, the one positively and the
negatively, the force of attraction increases rapi
they draw near to each other, being four times as
when twice as near, and a hundred times as
when ten times as near. Repulsion follows the
law; that is, when two balls are similarly elect
it requires four times the force to bring them tw
near to each other, and a hundred times the fo
bring them ten times as near as before.

SEC. 2. *Of Electrical Apparatus.*

134. Electrical machines afford the means of
mulating the electric fluid, so as to render its e
far more striking and powerful than they appear
simple experiments already recited. The *cy*

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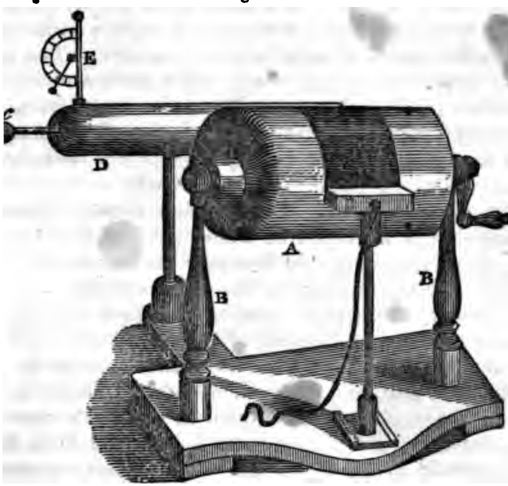
133. State the four laws of electrical attraction and repulsio

chine is represented in figure 58. Its principal ts are the cylinder, the frame, the rubber, and the

Fig. 58.



ne conductor. The *cylinder* (A) is of glass, from ht to twelve inches in diameter, and from twelve eighteen inches long. The *frame* (B B) is made hard wood, dried and varnished. The rubber (C) sists of a leathern cushion, stuffed with hair like pad of a saddle. This is covered with a black cloth, having a flap, which extends from the cush- over the top of the cylinder to the distance of an h from the points of the prime conductor, to be ntioned presently. The rubber is coated with an *algam*, composed of quicksilver, zinc, and tin, which paration has been found by experience to produce

34. Describe the electrical machine—the cylinder—the frame—the ber—the amalgam—*the prime* conductor.

a high degree of electrical excitement, when subjected to the friction of glass. The *prime conductor* (D) is usually a hollow cylinder of brass or tin, with rounded ends. It is mounted on a solid glass pillar, (a junk bottle with a long neck will answer,) with a broad and heavy foot made of wood to keep it steady. The cylinder is perforated with small holes, for the reception of wires (*c*) with brass knobs. It is important in an electrical machine, that the work should be smooth and free from points and sharp edges, since these have a tendency to dissipate the fluid, as will be more fully understood hereafter. For a similar reason, the machine should be kept free from dust, the particles of which act as points, and dissipate the electricity.

135. By the friction of the glass cylinder against the rubber, electricity is produced, which is received by the points, and thus diffused over the surface of the prime conductor, and may be drawn from it by the knuckle or any conducting substance. In order to indicate the degree of excitement in the prime conductor, the *Quadrant Electrometer* is attached to it, as is represented at E, figure 58. This electrometer is formed of a semi-circle, usually of ivory, divided into degrees and minutes from 0 to 180. The index consists of a straw, moving on the centre of the disk, and carrying at the other extremity a small pith-ball. The perpendicular support is a pillar of brass, or some conducting substance. When this instrument is in a perpendicular position, and not electrified, the index hangs by the side of the pillar, perpendicularly to the horizon; but when the prime conductor is electrified, it imparts the same kind of electricity to the index, repels it, and causes it to rise on the scale towards an angle of 90 degrees, which point indicates a full charge.

135. How is the electricity produced? Describe the quadrant electrometer, and show how it indicates the degree of the charge.

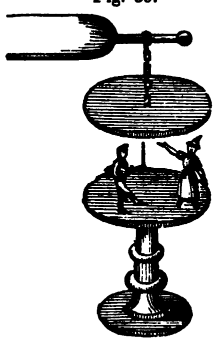
136. Let us now try a few experiments ...
n the machine ...
ctor will be charged ...
l remain fixed ...
the conducting power ...
e held in the hand and applied ... con-
ctor will not cause the index ...
l, because glass is a non-conductor ...
an iron rod thus applied will ...
l instantly, iron being a good conductor ...
g the fluid ready to escape ...
rough my person to the floor ...
n applying a knuckle ...
d, in the same manner ...
od conductor, as the fluid ...
e index falls. On the other hand ...
ax will not affect the index ...
nductor. So, if we hold a silk ...
read it will scarcely affect the ...
held by a linen thread ...
d the index will fall ...
arner to try in this way ...
eat variety of bodies. ...
e electrometer very little ...
em to be non-conductors ...
to fall, and are known as good ...
ill cause the index to ...
ourse imperfect conductors. ...
oistened with the breath or water ...
icate an increase of conducting power ...
f wood, as a broom-handle, ...
ith less power than a *short* stick of the same ... a
arge thread will conduct better than a small one

136. Experiments on the conducting power ... —the knuckle—sealing wax—a silk thread. ... these. What is the effect on conducting power produced by moisture —by increasing the length or size of a bad conductor?

Thus all the different circumstances affecting ducting power, may be ascertained; and knowledge of these relative powers, depend of managing the electric fluid, whether in th common electricity or in that of lightning.

137. The laws of *attraction* and *repulsion* verified by the aid of an electrical machi more strikingly than by the simple appara tioned in Articles 132 and 133. If we hang hair to the prime conductor, on turning the the hairs will recede violently from each c cause bodies similarly electrified repel ea By placing light bodies, as paper images, cotton, or light feathers, between one plate c with the prime conductor and another which i lated, as is represented in figure 59, (the up being hung to the pr ductor,) the *electrical d* be performed. The will first be attracted t per plate, but instantly the same electricity, t be repelled by the u attracted by the lower descending to the lat will give up their ch return again to the up to repeat the process, forming a kind of danc when performed by li ges of men and women very amusing. Most electrical machines are f with a variety of apparatus for illustrating th ples of electrical attractions and repulsions, s chime of bells, the electrical horse-race, the e

Fig. 59.



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137. Effect when a lock of hair is hung to the prime
How is the electrical dance performed?

nd mill, and the like; but these must be seen in order be fully understood, and therefore their exhibition left to the instructor.

138. The *Leyden Jar* is a piece of apparatus used for accumulating a large quan- y of electricity. It consists of a glass coated on both sides with tin foil, except space on the upper end, within two or ·ee inches of the top, which is either left re, or is covered with a coating of var- sh, or a thin layer of sealing wax. To mouth of the jar is fitted a cover of hard ked wood, through the center of which sses a perpendicular wire, terminating ove in a knob, and below in a fine chain at rests on the bottom of the jar. On presenting e knob of the jar near the prime conductor of an elec- cal machine, while the latter is in operation, a series sparks pass between the conductor and the jar, hich will gradually become more and more feeble, til they cease altogether. The jar is then said to *charged*. If we now take the *dis- arging rod*, (which is a bent wire, ned at both ends with knobs, and ulated by a glass handle, as in fig- 61, and apply one of the knobs the outer coating and bring the other the knob of the jar, a flash of intense ghtness, accompanied by a loud re- rt, immediately ensues. If, instead the discharging rod, we apply one nd to the outside of the charged jar, d bring a knuckle of the other hand to the knob of jar, a sudden and surprising *shock* is felt, convul-

Fig. 60.

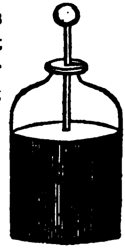
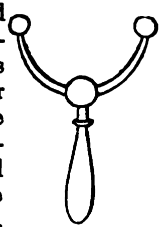


Fig. 61.



138. Define the Leyden Jar—describe it—how is it charged? How charged? How is the shock taken?

sing the arms, and when sufficiently powerfu through the breast.

139. The outside and the inside of a Le are always found in opposite states; that is knob connected with the inside we have imp itive electricity, (as in the mode of chargin described,) then the outside will be electrifi same degree with negative or resinous e Every spark of one sort of fluid that enter jar, drives off a spark of the same kind fron side, and leaves that in the opposite state. jar is insulated, (as when it stands on a glass so that the electricity cannot pass from the c ing, then it will take no charge. We may jar negatively instead of positively, by gras of the knob and presenting the outside to conductor. The positive electricity that outer coating, drives off ane qual quantity of kind from the inside, which escapes through of the operator and leaves the inner coating When the jar is thus charged, we must be set it down on a *glass* support before wi the hand; for if we place it on the table, a conductor, the electricity will immediately the outside to the inside, through the table, body of the operator, and he will receive a sh if he sets the jar on a non-conducting suppor communication will be formed between the of the jar, and consequently it will not disch

The *Electrical Spider* forms a pleasing i of the different states of two jars, one charge ly and the other negatively. It is contriv lows: Take a bit of cork and form a small l size of a pea, for the body of the spider. needle, pass a fine black thread backward

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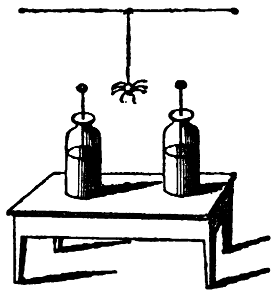
139. In what state are the two sides of a charged jar? charge a jar negatively? Why is it necessary to set it

wards through the sides of the cork, letting the threads project from it half or three-fourths of an inch on the opposite sides, to form the legs. Now suspend it from the centre of the body by a fine silk thread, between two jars, one charged positively and the other negatively, and placed on a table, as is represented in figure 62. The spider will first be attracted to the knob of the nearest jar, will imbibe the same electricity, be repelled, and attracted to the knob of the other jar, from which again it will be repelled, and so will continue to vibrate back and forth between the two jars, until it has restored the equilibrium between them by slowly conveying to the inside of each jar the electricity of the inner coating of the other.

Fig. 62.



Pointed conductors have a remarkable power of drawing off and dissipating the electric fluid when it has accumulated. If we apply one hand to the outer coating of a charged jar, and with the other bring a needle towards the knob, it will silently draw off all the charge, without giving any shock. And if, while we are charging a jar with the machine, we direct a pointed wire or a needle towards the machine, even at a much greater distance from it than the knob of the jar, the

Fig. 63.

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insulated support? Describe the electrical spider. Why does it vibrate from one jar to the other? Effect of points.

fluid will pass into the needle in preference to the jar. All apparatus, therefore, for confining electricity, requires to be free from sharp lines and points, and to terminate in round smooth surfaces.

SEC. 3. *Of Electrical Light and Heat.*

140. Electrical Light appears whenever the fluid is discharged in considerable quantities through a resisting medium. When electricity flows freely through good conductors, it exhibits neither light nor heat; but if such conductors suffer any interruption, as in passing through a small space of air, or even through an imperfect conductor, then light becomes manifest. We will suppose the experiment to be performed in a dark room, or in the evening, in a room very feebly lighted. A glass tube, rubbed with black silk, coated with a little electrical amalgam, will afford numerous sparks, with a slight crackling noise. A chain, hung to the prime conductor of a machine, will show a bright spark at every link. If we attach one end of the chain to the prime conductor, and hold the other end suspended by a glass tube, brushes or pencils of light will issue from various points along the chain. The spark seen in discharging the Leyden Jar, as in Article 138, is very intense and dazzling.

Fig. 64.

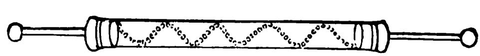

Figure 64 represents a glass cylinder, armed at each end with brass balls, and wound round, spirally, with a narrow strip of tin foil. At short intervals, small portions of the tin foil are cut out, so as to interru

140. When does electrical light appear? When does electricity exhibit neither light nor heat? Experiment with a glass tube—chain—a spiral tube. How may illuminated words be made to appear

circuit. Whenever a spark is passed through this apparatus, it appears beautifully luminous at every interruption in the tin foil. Words or figures of any kind may be very finely exhibited by coating a plate of glass with a strip of tin foil in a zig-zag line, from one corner to the opposite corner, diagonally. Then with the point of a knife, small portions of the tin foil are picked out in such a manner that the spaces thus left bare shall together constitute some word, as WASHINGTON. The spark in passing through the tin foil, will meet with resistance at all the places where the metal has been removed, and will there exhibit a bright light. Thus an illuminated word will appear at every spark received from the machine. If the machine is not sufficiently powerful to afford a spark strong enough to overcome the resistance occasioned by so many non-conducting spaces, then the illuminated word may be made to appear with great splendor, by making the plate form a part of the circuit between the inside and the outside of a charged Leyden Jar.

41. By means of the *Battery*, far more brilliant experiments may be performed than with a single jar. The Battery consists of a number of jars, twelve, for instance, so combined that the whole may be either charged or discharged at once. Large Leyden Jars, placed side by side in a box, standing on tin foil, which forms a conducting communication between the outer coatings, while the inner coatings are also in communication by a system of wires and knobs, answers the same purpose as a single jar of enormous size, and is far more convenient. When the battery is charged, and a chain is made to form a part of the circuit between the outside and inside, on discharging it the whole chain is most brilliantly illuminated.

41. The Battery—of what does it consist? Describe it. How is a chain *illuminated by the battery?* Great power of some batteries.

Rough lightning rods sometimes present a similar appearance when struck during a thunder storm. Batteries are sometimes made of sufficient power to kill small animals, and even men.

142. *Heat*, as well as light, attends the electric spark, although, except when the discharge is very powerful, as in the case of the battery, or of lightning, it is but feeble, sufficient to set on fire only the most inflammable substances. Alcohol and ether, two very inflammable liquids, may be fired by the spark, a candle may be lighted, and gun powder exploded. It is, however, difficult to set powder on fire by electricity, unless the spark is very strong.

143. The electric spark passes much more easily through *rarefied* air, than through air in its ordinary state. Thus, a spark which would not strike through the air more than four or five inches, will pass through an exhausted glass tube, four feet or more in length, filling all the interior with a soft and flickering light, somewhat resembling the Aurora Borealis. Hence, that phenomenon has been ascribed by some to electricity, though this is probably not its true explanation.

144. In *Thunder Storms*, we see electricity exhibited in a state of accumulation far beyond what we can create by our machines, and producing effects proportionally more energetic. A cloud presents a conductor insulated by the surrounding air, in which, in hot weather, electricity collects and accumulates as it would upon a prime conductor of immense size. By sending up a kite armed with points, electricity may be drawn from such clouds, and made to descend by a wire wound round the string of the kite. We

142. Does heat attend electricity? Give examples of bodies fired by it.

143. How does the spark pass through rarefied air? Explain the appearance of the Auroral tube.

144. How is electricity exhibited in thunder storms? Analogy between a cloud and a prime conductor. How may lightning be drawn

easily direct it upon a prime conductor, or charge
yden Jar with it, and examine its properties as we
d do in the case of ordinary electricity. By
experiments, it is found that the clouds are some-
positively and sometimes negatively electrified.
under storms, the lightning is usually nothing
than the electric spark passing from one cloud
other differently electrified, as it passes between
uter and inner coating of a Leyden Jar. The
appears in the form of a line, because it passes
viftly, just as a stick, lighted at the end and
ed in the air, forms a circle of light. The mo-
of the electric fluid is, to all appearance, instan-
us. Thunder is the report occasioned by the
ng together of the air, after it has been divided
e passage of the lightning. The cracking of a
, as already mentioned, is ascribed to the same
. The lash divides the air into two parts, which
ly rush together and occasion the sound. When
nder clap is very near us, the report follows the
almost instantly, and such claps are dangerous.
l cases, the lightning and the thunder actually
at the same moment, but when the discharge is
ne distance from us, the report is not heard till
time after the flash; for the light reaches the
nstantaneously, but the sound travels with com-
ive slowness, moving only about a mile in five
ds. We may, therefore, always know nearly
listant a thunder cloud is, by counting the number
conds between the flash and the report, and al-
g the fifth of a mile (or, more accurately, 1,130
to a second. (See Art. 124.)

5. Sometimes lightning, instead of passing from

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he clouds? How is the flash produced in thunder storms?—
loes it leave a bright line? What is thunder? How produced?
re the flash and the report sometimes together and sometimes
te?

cloud to cloud, discharges itself into the earth, then strikes objects that come in its route, as ho trees, animals, and sometimes man. As electi always selects, in its passage, the best condu Dr. Franklin first suggested the idea of protectin dwellings by means of *Lightning Rods.* If thes properly constructed, the lightning will always its passage through them in preference to any p the house, and thus they will afford complete p tion to the family. Sharp metallic points wer served by Dr. Franklin to have great power t charge electricity from either a prime conducto Leyden Jar, and this suggested their use in ligl rods. Metals, also, being the best conductors of tricity, would obviously afford the most proper rial for the body of the rod.

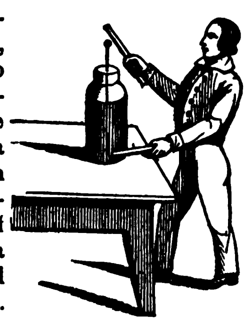
There are three or four conditions in the constr and application of a lightning rod, which are ess to insure complete protection. The rod must less than three-fourths of an inch in diameter—i be continuous throughout, and not interrupted by joints—it must terminate above in one or more points, of some metal, as silver, gold, or platin liable to rust—it must enter the ground to the of permanent moisture, which will be different ferent soils, but usually not less than six feet. thus constructed, will generally protect a space way equal to twice its height above the ridge house. Thus, if it rises fifteen feet above the it will protect a space every way from it of thirt It is usually best to apply the rod to the chim the house; or, if there are several chimneys, it to select one as central as possible. The k

145. What happens when lightning strikes to the earth? L rods—influence of points and conductors—power of metals- the rod—to be continuous—how terminated above and below much space will a rod protect? How applied to a house?

y, being usually the only one in which fires are ined during the season of thunder storms, re- to be specially protected, since a column of rising from a chimney, is apt to determine the of the lightning in that direction. If, there- e lightning rod is attached to some other chim- the house, either a branch should proceed from e kitchen chimney, or this should have a sep- od. As lightning, in its passage from a cloud arth, selects tall pointed objects, it often strikes nd it is, therefore, never safe to take shelter rees during a thunder storm. Persons struck y lightning, are sometimes recovered by dash- repeated buckets of water.

4. *Of the Effects of Electricity on Animals.*

Fig. 65.



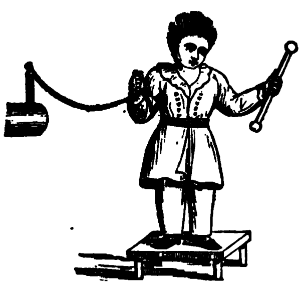
When we apply a e to the prime conduc- n electrical machine, eive the spark, a sharp mewhat painful sensa- felt. If we receive rge of a Leyden Jar, a s experienced which or less severe, accord- the size and power of . A battery gives a still more severe, and be even dangerous. ng, it is well known, nes prostrates and kills men and animals. A ient method of taking the *shock*, is to charge a

he kitchen chimney? May we take shelter under trees? estore people struck by lightning?
ensation to the knuckle—effects of a jar—of a battery. What enient mode of *taking* the shock? Sensations produced by

quart jar, place it on a table, and grasp
hand a metallic rod, apply one rod to th
the jar, and touch the other to the knob co
the inside. If the charge is feeble, it wil
in the arms; if it is stronger, it will be
breast; and it may be sufficiently powerfu
the whole frame. Any number of pers
taking hold of hands, all receive the shoc
instant. The first must touch the outside
the knob of the jar. Whole regiment
electrified at once in this way.

147. Electricity is sometimes employe
and is thought to afford relief in various
may be applied either to the whole syste
to any individual part, by making that par
tion of the communication between the in

Fig. 66.



outside of
fluid may
milder fo
of the *El*
This is a
resting o
The patie
sits on t
holds a c
ed with th
ductor, w
chine is t
produces
exciteme
whole system; the hair stands on end; s
taken from all parts of the person, as
conductor; and the patient may commun

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a feeble charge—by a strong—by a powerful charge
number of persons be electrified at once?

147. How is electricity employed medicinally? H
the electrical stool?

shock to any one that comes near him, or may set on fire ether and other inflammable substances, by merely touching them with a rod, or pointing towards them.

148. Several *fishes* have remarkable electrical powers. Such are the Torpedo, the Gymnotus, and the Silurus. The Gymnotus, or Surinam eel, is found in the rivers of South America. Its ordinary length is from three to four feet; but it is said to be sometimes twenty feet long, and to give a shock that is instantly fatal. Thus, it paralyzes fishes, which serve as its food, and in the same manner it disables its enemies and escapes from them. By successive efforts, electral fishes exhaust themselves. In South America, the natives have a method of taking them, by driving wild horses into a lake where they abound. Some of the eels are very large, and capable of giving shocks so powerful as to disable the horses; but the eels themselves are so much exhausted by the process, as to be easily taken.

CHAPTER VIII.

MAGNETISM.

DEFINITIONS—ATTRACTIVE PROPERTIES—DIRECTIVE PROPERTIES—VARIATION OF THE NEEDLE—DIP—MODES OF MAKING MAGNETS.

149. Among the ores of iron, there is found an ore of a peculiar kind, which has the power of attracting iron filings, and other forms of metallic iron, and is called the *loadstone*. This power can be imparted to bars of steel, which are denominated *magnets*. The unknown power which produces the peculiar effects of the magnet, is called *magnetism*. This name is

148. What of electrical fishes? Give an account of the Gymnotus. How do the natives take electrical fishes in South America?

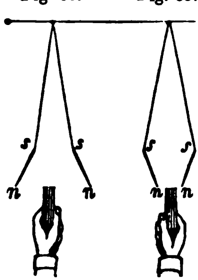
149. What is the loadstone, and magnets? Define *Magnetism*—two

also applied, as at the head of this chapter, to that branch of Natural Philosophy which treats of the magnet. *Magnetic bars* are thick plates of iron or steel, commonly about six inches long. If a magnetic bar be placed among iron filings, they will arrange themselves around a point at each end, forming tufts,

Fig. 67.

as is shown in figure 67. These two points are called the *poles*, and the straight line that joins them, the *axis* of the magnet. If we suspend, by a fine thread, a small needle, and approach towards it either pole of a metallic bar, the needle will rush towards it and attach itself strongly to the pole. By rubbing the needle on one of the poles of the magnet, it will itself imbibe the same power of attracting iron, and become a magnet, having its poles. If we now bring first one pole of the magnetic bar towards the needle, and then the other pole, we shall find that one attracts, and the other repels the needle. Figure 68 represents two large sewing needles, magnetized, and suspended by fine threads. On approaching the north pole of a magnetic bar to the north poles of the needles, they are forcibly repelled; but on applying the south pole of a bar, as in figure 69, the north poles of the needles are attracted towards it.

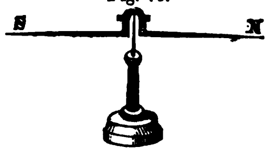
Fig. 68. Fig. 69.



senses in which the word is used. What are magnetic bars? What are the poles—the axis? How may a needle be magnetized? How are its properties changed by this process?

150. Let us suppose that the long needle represented in figure 70, has been rubbed on a magnet, so as to imbibe its properties, or to become *magnetized;* then, on balancing it on a pivot, it will of its own accord place itself in nearly a north and south line, and return forcibly to this position when drawn aside from it. This property is called the *directive*, while the other is called the *attractive*, property of the magnet. That end which points northward, is called the *North Pole* of the magnet, and that end which points southward, is called the *South Pole.* Every magnet has these two poles, whatever may be its size or shape. A magnetic bar has usually a mark across one end, to denote that it is the north pole, the other, of course, being the south pole. If the north pole of a bar be brought towards the north pole, N, (Fig. 70,) of the needle, it will repel it, and the more forcibly in proportion as we bring it nearer to N. On the contrary, if the north pole of the bar be brought towards the south pole S of the needle, it will attract it. Also, if we present the south pole of the bar first to one pole of the needle, and then to the other, we shall find that the bar will repel the pole of the same name with its own, and attract its opposite. These facts are expressed by the proposition that *similar poles repel, and opposite poles attract each other.* When a magnetic bar is laid on a sheet of paper, and iron filings are

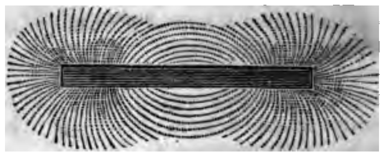
Fig. 70.



150. Explain the *directive* property. Which is the north and which the south pole? How is the north pole distinguished? Effect when the north pole of the bar is brought near the north pole of the needle—when the north pole is brought towards the south pole? State the general fact. What takes place when a magnetic bar is placed among iron filings?

sprinkled on it, they will arrange themselves in cur around it, as in figure 71.

Fig. 71.



151. The magnetic needle, when freely suspen seldom points directly to the pole of the earth, bu deviation from that pole, either east or west, is ca the *variation* of the needle. A line drawn on the face of the earth, due north and south, is called a *ridian line.* The needle usually makes a great less angle with this line. Its direction is callec *magnetic meridian*, and the place on the earth to w it points, is called the *magnetic pole.* The eartl two magnetic poles, one in the northern, the oth the southern hemisphere. The north magnetic is in the part of North America lying north of] son's and west of Baffin's Bay, in latitude 70°. variation of the needle is different in different c tries. In Europe, the needle points nearly N and S. E.; while in the United States it deviate where but a few degrees from north and south; along a certain series of places, passing through V ern New York and Pennsylvania, the variation is ı ing; that is, the needle points directly north and s At the same place, moreover, the variation of needle is different at different periods. For a series of years, the needle will slowly approacl

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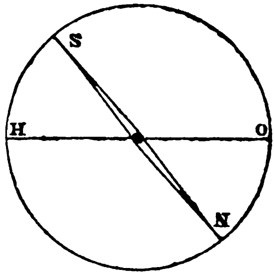
151. What is meant by the variation of the needle? Wh meridian line?—the magnetic meridian? Situation of the nortl netic pole? How is the variation of the needle in Europe? H the United States? Where does the line of no variation run?

North pole, come within a certain distance of it, and then turn about and again slowly recede from it. At Yale College, the variation in 1843, was 6½ degrees West, and is increasing at the rate of 4½ minutes a year.

152. A needle first balanced on its center of gravity, and then magnetized, no longer retains its level, but it points below the horizon, making an angle with it, called the *Dip of the needle.*

Fig. 72.



The dipping needle is shown in figure 72, adapted to a graduated circle in order to indicate the amount of the depression, and is sometimes fitted with screws and a level to adjust it for observation. The dip of the needle varies very much in different parts of the earth, being in general least in the equatorial, and greatest in the polar regions. At Yale College, it is about 73 degrees, being greater than is exhibited in the figure.

153. The directive property of the needle has two most interesting and important practical applications, in surveying and navigation. The compass needle, in order to keep it at a horizontal level, and prevent its dipping, has a counterpoise on one side, which exactly balances the tendency to point downward. By the aid of this little instrument, lands are measured, and boundaries determined ; the traveller finds his way

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does the variation change at any given place? How is it at New Haven?

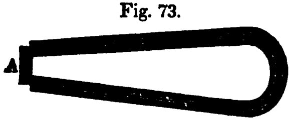
152. What is the *Dip* of the needle? Describe figure 72. Where is the dip of the needle greatest? Where least? Its amount at Yale College?

153. What are the two leading applications of the needle? How is the compass needle kept from dipping? To what uses is it applied?

through unexplored forests and deserts; and mariners guide their ships through darkness and tempests, and across pathless oceans.

154. There are various methods of ***making compass needles***, or artificial magnets. Soft iron readily receives magnetism, but as readily loses it; hard steel receives it more slowly, but retains it permanently. It is a singular property of a magnet, whether natural or artificial, that, like virtue, it loses nothing by what it imparts to another. In fact, such an exercise of its powers is essential to their preservation. The strongest magnet, if suffered to remain unemployed, gradually loses power. Magnets, therefore, and loadstones, are kept loaded with as much iron as they are capable of holding, called their *armature*. If we simply rub a penknife on one pole of a magnet, we render it magnetic as will be indicated by its taking up iron filings or sewing needles. Magnetism is most readily imparted by a bar, when both its poles are made to act together. This is done by giving the bar the form of a horse shoe, as in figure 73. To magnetize a needle, we lay it flat on a table, and place the two poles of the horse shoe magnet near the middle, and rub it on the needle, backwards and forwards, first towards one end and then towards the other, taking care to pass over each half of it an equal number of times. The needle may then be turned over, and the same process performed on the other side, when it will be found strongly and permanently magnetized.

Fig. 73.



154. How is the compass needle made? What is said of soft iron and hard steel? How is the strength of the magnet affected by action or inaction? What is the armature? How to magnetize a penknife. Why is a bar bent into the horse-shoe form? How to magnetize a needle with it.

CHAPTER IX.

OPTICS.

DEFINITIONS—REFLEXION AND REFRACTION—COLORS—VISION—MICROSCOPES AND TELESCOPES.

155. OPTICS *is that branch of Natural Philosophy which treats of Light.* Light proceeds from the sun, a lamp, and all other luminous bodies in every direction, in straight lines, called *rays.* If it consists of matter, its particles are so small as to be incapable of being weighed or measured, many millions being required to make a single grain. Some bodies, as air and glass, readily permit light to pass through them, and are called *transparent;* others, as plates of metal, do not permit us to see through them, and are called *opake.* Any substance through which light passes, is called a *Medium.* Light moves with the astonishing velocity of 192,500 miles in a second. It would cross the Atlantic Ocean in the sixty-fourth part of a second, and in the eighth part of a second, would go round the earth. When light strikes upon bodies, some portion of it enters the body, or is *absorbed,* and more or less of it is thrown back, and is said to be *reflected;* when it passes through transparent bodies, it is turned out of its direct course, and is said to be *refracted.* The light of the sun consists of seven different colored rays, which, being variously absorbed and reflected by different bodies, constitute all the varieties of *colors.* Light enters the eye, and forming within it pictures of external objects, thus gives the sensation of vision. The knowledge of the properties of light, and the nature of vision, has given rise to the invention of many noble and excellent instruments,

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155. Define Optics—terms rays, transparent, opake, and medium. When is light said to be reflected? When refracted? Of what do the

which afford wonderful aid to the eye, such as the *microscope* and the *telescope*. Let us examine more particularly these interesting and important subjects, under separate heads.

SEC, 1. *Of the Reflexion and Refraction of Light.*

156. When rays of light, on striking upon some body are turned back into the same medium, they are said to be *reflected*. Smooth polished surfaces, like mirrors and wares of metal, reflect light most freely of any, and hence their brightness. Most objects, however, are seen by reflected light; few shine by their own light. Thus, the whole face of nature owes its brightness and its various colors to the light of the sun by day, and to the light of the moon and stars by night. The rays that come from these distant luminaries, fall first upon the atmosphere, and are so reflected and refracted from that as to light up the whole sky, which, were it not for such a power of scattering the rays of light that fall upon it, would be perfectly black. On account of the transparency of the atmosphere, the greater part of the sun's rays pass through it, and fall upon the surface of the earth, and upon all objects near it. These reflect the light in various directions, and are thus rendered visible by that portion of the light which proceeds from them to the eye.

157. When a ray of light strikes upon a plane surface, the angle which it makes with a perpendicular to that surface, is called the *angle of incidence*, and the angle which it makes with the same perpendicular, when reflected, is called the *angle of reflexion*. The

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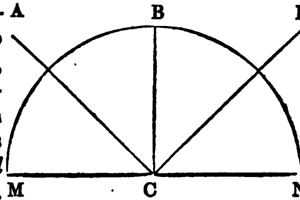
sun's rays consist? To what inventions has the study of Optics given rise?

156. When are rays of light said to be reflected? By what light are most objects seen? Show how the atmosphere and most things on the earth are illuminated.

157. Define the angle of incidence and of reflexion. Equality be-

angle of reflexion is equal to the angle of incidence. Thus, a ray of light, A C, striking upon a plane mirror, M N, at C, will be reflected off into the line C B, making the angle of incidence, M C A, equal to the angle of reflexion, N C D. It is not necessary that the surface on which the light strikes should be a *continued* plane; the small part of a curved surface, on which a ray of light falls, may be considered as a plane, touching the curve at that point, so that the same law of reflexion holds in curved as in plane surfaces. Now the grains of sand on a sandy plain, present surfaces variously inclined to each other, which scatter the rays of the sun in different directions, many of which enter the eye, and make such a region appear very bright; while a smooth surface, like a mirror, or a calm sheet of water, reflects the light that falls on it, chiefly in one direction, and hence appears bright only when the eye is so situated as to receive the reflected beam. Thus, the ocean appears much darker than the land, except when the sun shines upon it at such an angle as to throw the reflected beam directly towards the eye, as at a certain hour of the morning or evening, and then the brightness is excessive.

Fig. 74.



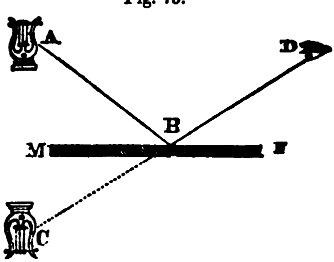
158. An object always appears in the direction in which *the last ray of light from it comes to the eye.* Thus, we see the sun below the surface of a smooth lake or river, because every ray of light, being reflected from the water as from a mirror, comes to the

tween these two angles. Explain figure 74. Does the same law hold for curved surfaces? Which appears darkest, the ocean or land, in the light of the sun?

eye in the direction in which the image appears; and if the light of a star were to change its direction a hundred times in coming through the atmosphere, we should see the star in the direction of the last ray, in the same manner as if none of the other directions had existed. This principle explains various appearances presented by mirrors, of which there are three kinds—plane, concave, and convex.

159. A common looking-glass furnishes an example of a *Plane Mirror*. If we place a lamp before it, rays of light are thrown from the lamp upon every part of the mirror, but we see the lamp by means of those few of the rays only which are reflected to the eye; all the rest are scattered in various quarters, and do not contribute at all to render the object visible to a spectator at any one point, although they would produce, in like manner, a separate image of the lamp wherever they entered an eye so situated as to receive them. Hence, were there a hundred people in the room, each would see a separate image, and each in the direction in which the rays came to his own eye.

Fig. 75.



We will suppose M N to be the looking-glass, having a

158. In what direction does an object always appear? Example in the sun—in a star. What are the three kinds of mirrors?

159. Explain how the image is formed in a plane mirror. What *rays only* enable us to see the image? Explain Fig. 75. How far harp placed before it, and the eye of the spectator at D. Of all the rays that strike on the glass, the spectator will see the image by those only which strike the mirror in such a direction, A B, that when reflected from the mirror at the same angle on the other side, they shall enter the eye in the direction B D. The image will appear at C, and *will be just as far behind the mirror as the harp is before it.* This last principle is an important one, and it must always be remembered, that every point in an object placed before a plane mirror, will appear in the image just as far behind the mirror as that point of the object is before it; so that the image will be an exact copy of the object, and just as much inclined to the mirror. We learn, also, the reason why objects appear inverted when we see them reflected from water, as the surface of a river or lake, since the parts of the object most distant from the water, that is, the top of the object, will form the lowest part of the image.

160. If we take a looking-glass and throw an image of the sun on a wall, on turning the mirror round we shall find that the image moves over twice as many degrees as the mirror does. If the image is at first thrown against the wall of a room, horizontally, (in which case the mirror itself would be perpendicular to the horizon,) by turning the mirror through half a right angle, the place of the image would be changed a whole right angle, so as to fall on the ceiling over head. A common table glass, which turns on two pivots, being placed before a window when the sun is low, will furnish a convenient means of verifying this principle.

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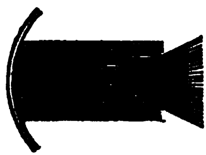
is the image behind the mirror? How far is each point in the image behind the mirror? Why do objects appear inverted when reflected from water?

160. If a mirror be turned, how much faster does the image move than the mirror? State how the experiment is performed.

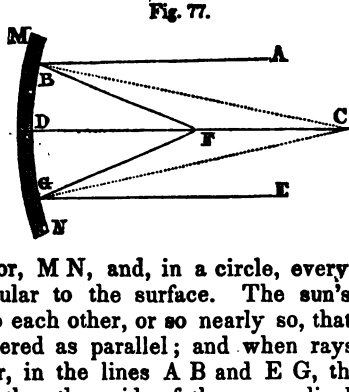
161. A *Concave Mirror* collects rays of light we hold a small concave shaving-glass, for inst towards the sun, it will collect the whole bea light that falls upon it into one point, called the *j* Figure 76 will give some id the manner in which parallel strike a concave mirror, conv to a focus, and then diverg The angle of reflexion is equ the angle of incidence here well as in a plane mirror; bu perpendicular to a curved su

Fig. 76.



is the radius of the circle of which the curve part. Thus, the line C B is the radius of the

Fig. 77.



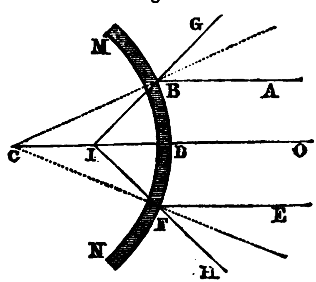
cave mirror, M N, and, in a circle, every ra perpendicular to the surface. The sun's r parallel to each other, or so nearly so, that t be considered as parallel; and when rays the mirror, in the lines A B and E G, the flected on the other side of the perpendicula ing in a common focus, F, which point is *focus of parallel rays.* Into this point, c space around it, a concave mirror will colle

161. What is the office of a concave mirror? Expe shaving-glass. What forms the perpendicular to a cur What is the point called where parallel rays are collec

of the sun, increasing in heat in the same proportion as the illuminated space at F is less than the whole surface of the mirror. In large concave mirrors, the heat at the focus often becomes very powerful, so as not only to set combustibles on fire, but even to melt the most infusible substances. Hence the name focus, which means a *burning* point. If a lamp is placed at F, the rays of light proceeding from it in the lines F G and F B, will strike upon the mirror and be reflected back into the parallels, G E and B A. We shall see hereafter how useful this property of concave mirrors,—to collect parallel rays of light into a focus,—is in the construction of that most noble of instruments, the telescope.

A *Convex Mirror*, on the other hand, *separates* rays of light from each other, still observing the same law, that of making the angle of incidence equal to the

Fig. 78.



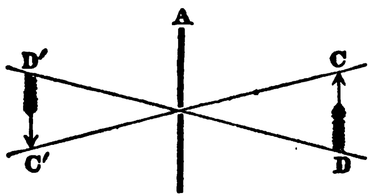
angle of reflexion. In figure 78, the parallel rays, A B, O D, E F, are represented as falling on a convex mirror, M N. A B and E F, being reflected to the other sides of the radii, C B and C F, are separated

said of the heat at the focus? When a lamp is placed in the focus, how will its light be reflected?

from each other, and form the image at I, whi
called the *imaginary focus* of parallel rays; becau
this point, the parallel rays that fall upon the m
seem to meet in a focus, behind the mirror, a
diverge again into the lines B G and F H.

162. Whenever the rays of light from the diffi
parts of an object cross each other before formin
image, the image will be *inverted*. It is manifest
figure 79, that the light by which the top of the o

Fig. 79.



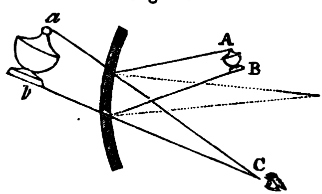
is represented forms the bottom of the image, a
light from the bottom of the object forms the to
image, the two sets of rays crossing each othe
hole in the screen. It is always essential to
tinctness of an image, that the rays which
from every point in the object, should be ar
corresponding points in the image, and shou
accompanied by light from any other source
screen like that in the figure, when interj
mits only those rays from any point in the
are very near together and nearly parallel to
to pass through the opening, after which th
straight forward and form the correspond
the image; while rays coming from any
the object cannot fall upon the point occ

162. In what case will the image appear inverte
Fig. 79. What is essential to the distinctness of
rays only does the screen permit to pass?

pencil, but each finds an appropriate place of
a in the image, and all together make a faithful
entation of the object.

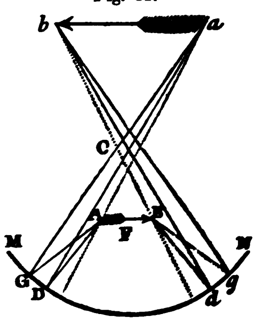
. Concave mirrors form *images* of objects, by
ing the rays from each point of the object into
ponding points in the image, unaccompanied by
om any other quarter. If the object be nearer

Fig. 80.



he focus, as in figure 80, a magnified image ap-
behind the mirror, and in its natural position;
the object be between the focus and the center,
age is before the mirror, on the other side of the
, larger than the object,
nverted, as it is in fig-
l, where the small ar-
A B, situated between
cus and the center of
irror, is reflected into
nage *a b*, inverted and
than the object. These
may be verified in a
oom, by placing a lamp
ferent distances from a
ve mirror. As such
rs form their images in
ir without any visible

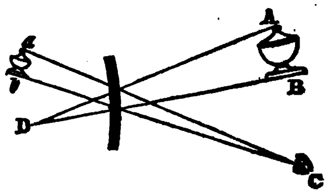
Fig. 81.



How do concave mirrors form images? When the object is
the . . . the focus, how does the image appear? How
. . . ocus? How may these cases be verified?

support, they have sometimes been employed by jugglers to produce apparitions of ghostly figures, drawn swords, and the like, which were made to appear in terrific forms, while the apparatus by which they were produced, was entirely concealed from the spectators.

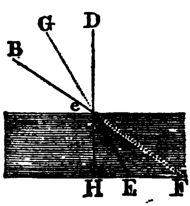
Fig. 82.



Convex mirrors give a diminished image of any object placed before it, representing it in its natural position, and behind the mirror, as in figure 82.

164. *Refraction is the change of direction which light undergoes by passing out of one medium into another.* When light passes out of a rare medium, like air, into a dense medium, like water, it is turned *towards* a perpendicular; when it passes out of a dense into a rare medium, it is turned *from* a perpendicular. When the ray of light, B C, passes out of air into water, it will not proceed straight forward in the line C F, but will go in the line C E, nearer to the perpendicular, C H; and light proceeding from an object under water at E would, on passing into the air at C, turn from the perpendicular into the line C B. Since

Fig. 83.

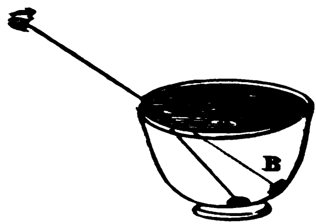


What use is made of concave mirrors by jugglers? How do convex mirrors represent objects?

164. Define refraction. How is light reflected by passing out of air *into* water—out of water into air? Explain Fig. 83. Also, Fig. 84.

lways appear direction in ie light finally o the eye, the an image is by its light through a re- nedium before s the eye. Fig. sents a bowl nall coin at the

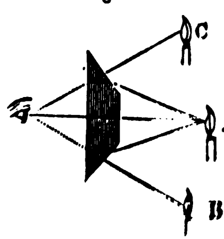
Fig. 84.



An eye situated as in the figure, would not see ; but, on turning water into the bowl, the coin visible at B, because the light proceeding from is bent towards the eye in passing out of the For a similar reason, an oar in water appears part immersed being elevated by refraction. om of a shallow river appears higher than it and people have been drowned by attempting river which, from the effect of refraction, ap- ss deep than it was.

'he Multiplying Glass many images of an there are surfaces, h surface refracts the t falls upon it, in a angle from the oth- course the rays meet in the same number nt directions, and the pears in the direction

Fig. 85.



The candle at A, Fig. 85, sends rays to he three surfaces of the glass. Those which perpendicularly, pass directly through the

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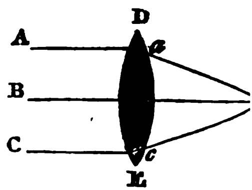
in water appears bent ? How does refraction affect the pth of a river ?

ribe the multiplying glass, and explain its ef glass to the eye, without change of direction, form one image in its true place at A. But the which fall on the two oblique surfaces, have thei rections changed both in entering and in leaving glass, (as will be seen by following the rays in figure,) so as to meet the eye in the directions and C. Consequently, images of the candle formed, also, at both these points. A multiplying has usually a great many surfaces inclined to one other, and the number of images it forms is pro tionally great.

166. This property of light,—the power of ha its direction changed by refraction,—is converte very important and interesting uses by means of LENSES. A lens is exemplified in a common sunglass, (or even in a spectacle glass,) and is either convex or concave. Convex lenses, like concave mirrors, *collect* rays of light. In figure 86, the parallel rays, A *a* and are collected along with the central ray (whicl ing perpendicular to the surfaces of the lens, su no refraction,) into a common focus in F. If I h sun-glass, or a pair of convex spectacles toward sun, the whole beam that falls upon the glass wi collected into a small space, forming a bright p or focus, at a certain distance from the lens on side opposite the sun, where it may be received screen or sheet of white paper. A *concave* lens,

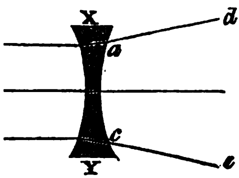
Fig. 86.



166. To what important and interesting uses is the power of to undergo refraction converted? What instruments are used fo purpose? What is the office of a convex lens? Describe Fi Examples in a sun glass and spectacles.

rex mirror, *separates* rays of light. Thus, in figure 87, the solar beam is spread over a greater space on the screen than the size of the lens, indicating that the rays are separated from each other by passing through the lens. Hence, concave lenses do not form images as convex lenses do,

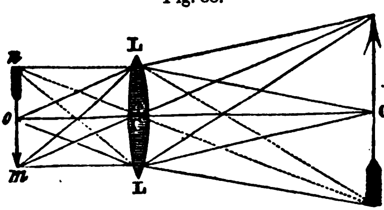
Fig. 87.



e therefore but little employed in the construc- optical instruments.

. A convex lens, like a concave mirror, forms *ıge* of an object without, by collecting all the s of rays that proceed from every point of the and fall upon the lens, into corresponding points place of the image. The image is inverted

Fig. 88.



e the pencils of rays cross each other, those ne top of the object going to the bottom of the and those from the bottom going to the top. figure, the central ray of each pencil (called the nd the extreme rays are represented. The ex-

low does a convex … age? Why is the image in- What is the *axis* o … Where do the axes cross er? Great numb… ceed from every point in t.

treme rays cross each other in the centre of th
and thus necessarily produce an inverted imag
we must conceive of a great number of rays pr
ing from every point in the object, and each
covering the whole lens, which collects them se
into distinct points, each occupying a separate
in the image.

168. If we place a lamp in the focus of a le
rays that proceed from it and pass through th
go out parallel, and will never come to a focus
other side, so as to form an image. But if we r
the lamp further from the lens, so as to make th
fall upon the lens in a state less diverging, then
collect them into a distinct image on the othe
which image will be large in proportion as it i
distant from the lens. As the object is witl
from the lens, the image approaches it; when tl
at equal distances from the lens, they are equal i
but when the object is further from the lens tl
image, the image is less than the object. The
ciples lead to an understanding of those inte
and wonderful instruments, the Microscope a
Telescope, to which our attention will herea
directed.

SEC. 2. *Of Colors.*

169. The philosophy of colors has been u
chiefly by means of the *Prism.* A Prism is a
gular piece of glass, usually four or five inche
presenting three plane smooth surfaces. Wh
look through the prism, all external objects ap

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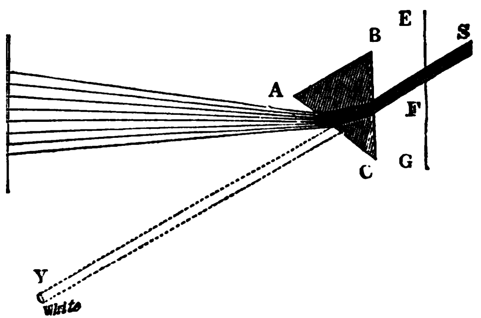
168. How do the rays go out when a lamp is placed in th
How when the lamp is farther from the lens than the focus?
the size of the image affected by its distance from the lens?
the image changed by withdrawing the lamp?

169. By what instrument has the philosophy of colors bee
ed? Define a prism. What appearances does it present w

brilliant hues, diversified by the various colors ιinbow. The reason of this is, that light con- seven different colors, which, when in union h other, compose white light; but when sepa- ›pear each in its own peculiar hue. The dif- lors are as follows—violet, indigo, blue, green, orange, red. The prism separates the rays light, in consequence of their having the prop- ındergoing different degrees of refraction in through it, the violet being turned most out of ;e and the red least, and all the others differ- ng themselves in this respect, as is shown in ›wing diagram. E F represents the window

Fig. 89.



›f a dark room, through a small opening in beam of solar rays shines. They fall on the B C, and are refracted, by which they are pwards, but in different degrees, the red least 'iolet most. By this means they are separated h other, and lie one above another on the op-

h it? Why? Seven colors of the spectrum. Why does separate the different colors? Explain Fig. 89. How :ompose the spectrum into white light?

posite wall, constituting the beautiful object called the *solar spectrum.* We may now introduce a double convex lens into the spectrum, just behind the prism, and collect all the rays which have been separated by the prism, and they will recompose white light. The elongated spectrum on the wall, presenting the seven primary colors, will vanish, and in the place of it will appear a round image of the sun as white as snow.

170. We may now learn the reason why so many different colors appear when we look through the prism. The leaves of a tree, for example, seem to send forth streams of red light on one side and of violet on the other. The intermediate colors lap over, and partly neutralize each other, while on the margin each color exhibits its own proper hue.

171. The *rainbow* owes its brilliant colors to the same cause, namely, the production of the individual colors that compose solar light, in consequence of the separation they undergo by refraction in passing through drops of water. Although drops of water are small objects, yet rays of light are still smaller, and have abundant room to enter a drop of water on one side, to be reflected from the opposite surface, and to pass out on the other side, as is represented in the following figure. The solar beam enters the drop of rain and some portion (a very small portion is sufficient) being refracted to B, then reflected and finally refracted again in leaving the drop, is conveyed to the eye of the spectator. As in undergoing these two refractions, some rays are refracted more than others, consequently they are separated from each other, and coming to the eye of the spectator in this divided state, produce

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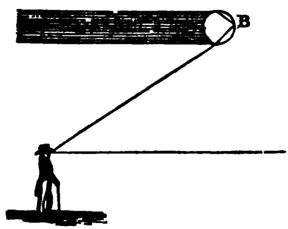
170. Why do so many different colors appear when we look through the prism? Explain the appearance of the leaves of a tree.

171. To what does the rainbow owe its colors? Explain how the separation of colors is produced. To what part of the bow does the *line pass* which joins the sun and the eye of the spectator? How high

each its own color. The spectator stands with his back to the sun, and a straight line passing from the

Fig 90.



sun through the eye of the spectator, passes also through the center of the bow. When the sun is setting, so that this line becomes horizontal, the summit of the bow reaches an altitude of about 42°, and the bow is then a semicircle. When the sun is 42° high, the same line would pass 42° below the opposite horizon, and the summit of the bow would barely reach the horizon. When the sun is between these two altitudes, the bow rises as the sun descends, composing a larger and larger part of a circle until, as the sun sets, it becomes an entire semicircle.

172. The varied colors that adorn the face of nature, as seen in the morning and evening cloud, in the tints of flowers, in the plumage of birds and wings of certain insects, and in the splendid hues of the precious gems, arise from the different qualities of different bodies in regard to the power of refracting or of reflecting light. When a substance reflects all the prismatic rays in due proportion, its color is white; when it absorbs them all, its color is black; and its color is

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does the top of the bow reach when the sun is setting? Where is it when the sun is 42° above the western horizon? When the sun is between these *two points?*

blue, green or yellow, when it happens to reflect one of these colors, and to absorb all the others of the spectrum. These hues are endlessly varied by the power natural bodies have of reflecting a mixture of some of the primary colors to the exclusion of others, every new proportion producing a different shade.

SEC. 3. *Of Vision.*

173. Whenever we admit into a dark room through an opening in the shutter, light reflected from various objects without, an inverted picture of these objects will be formed on the opposite wall. A room fitted for exhibiting such a picture, is called a *Camera Obscura*. In a tower which has a window opening towards the east, upon a beautiful public square, containing churches and other public buildings, and numerous trees, and the various objects of a populous city, a little dark chamber is fitted up for a camera obscura, having a white concave stuccoed wall opposite to the window, ten feet from it, and all the other parts of the room painted black. The afternoon, when the sun is shining bright in the west, and all objects seen to the east present their enlightened sides towards the window, is the time for forming the picture. For this purpose, a round hole about three inches in diameter is prepared in the shutter, which admits the only light that can enter the room. The room is made black every where except the wall that is to receive the picture, otherwise light would be reflected from different parts of the room upon the picture; whereas it is essential to its distinctness, that the image should be unso-

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172. How are the colors of natural objects produced? When is the color white, or red, or blue? How are the colors varied?

173. How may a picture be formed in a dark room? What is it called? Describe the Camera Obscura mentioned. When is th- for forming the picture? Why is the room painted black, a wall opposite the window?

companied by light from any other source. The wall that is to receive the picture is made concave, so that every part of it may be equally distant from the orifice in the shutter.

174. We now close the shutter, and instantly there appears on the opposite wall a large picture, representing all the varied objects of the landscape seen from the window, as churches, houses, trees, men and women, carriages and horses, and in short every thing that is in view of the window, including the blue sky, and a few white clouds that are sailing through it. Each is represented in its proportionate size and color, and if it is moving, in its true motion. Two circumstances, only, impair the beauty of the picture; one is, that it is not perfecly distinct, the other, that it is inverted—the trees appear to grow downward and the people to walk with their feet above their heads. The picture appears indistinct, because the opening in the shutter is so large that rays coming from different objects fall upon the picture and mix together, whereas each point in the image must be formed alone of rays coming from a corresponding point in the object. We will therefore diminish the size of the opening by covering it with a slide containing several holes of different sizes. We will first reduce the diameter to an inch. The picture is now much more distinct, but yet not perfectly well defined. We will therefore move the slide, and reduce the opening to half an inch. Now the objects are perfectly well defined, for through so small an opening none but the central ray, or axis, of each pencil can enter, and each axis will strike the opposite wall in a point distinct from all the rest. But, though the picture is no longer confused, yet it lacks brightness, for so few rays scattered over so large a

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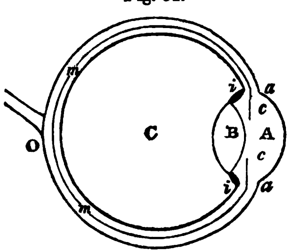
174. On closing the shutter, what [illegible] [illegible]es? What two circumstances impair th[illegible] distinct—How rendered mo[illegible]

surface, are insufficient to form a bright
will now remove the slide, open the origi
three inches, which lets in a great abund
and we will place immediately before
(within the room,) a convex lens of te
which will collect all the scattered rays
foci, and thus form a picture at once distin
so that the most delicate objects without,
bling of the leaves of the trees, and the
tions of animals, are all very plainly discer
one thing is wanting to make the picture
that is, to turn it right side upwards.
done, and is done in some forms of the can
but for our present purpose, which is to
principles of the eye, where the image f
inverted, it is better as it is.

175. The
mera obscur
nalogy betwe
pal parts an
vances empl
a picture of
jects, as in t
dark chambe
very striking
son. Figure
the human ey
circular char

Fig. 91.



black on all sides except the back part, call
which is a delicate white membrane, li
gauze, spread to receive the image. The
the eye, A, is a lens of a shape exactly a
purpose it is intended to serve, which pro

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orifice is small—What does the picture now lack? I
at once well defined and bright?

175. Analogy of the eye to the Camera Obscura. I
from Fig. 91.

s to receive the light that comes in sideways, and es it into the eye. The *pupil* is an opening between d *c*, like the opening in the window shutter, just be- which is a convex lens, B, which collects all the ;ered rays, and brings each pencil to a separate fo- where they unite in forming a bright and beautifully nct image of all external objects. O represents *optic nerve*, by which the sensations made on the ıa are conveyed to the brain. The substances ı which the several parts of the eye, A, B, and C, filled, are limpid and transparent, and purer than clearest crystal.

76. It is essential to distinct vision, that the rays ch enter the eye should be brought accurately to cus at the place of the retina; and in ninety-nine ɜs out of a hundred, this adjustment is perfect. But few instances, the lens, B, called the *crystalline* ıor, is too convex, and then the image is formed be- it reaches the retina. This is the case with near- ıted people. Their eyes are too convex; but by ıring a pair of concave spectacles, they can destroy excess of convexity in the eye, and then the crys- ine lens will bring the light to a focus on the retina the sight will be distinct. Sometimes, particu- y as old age advances, the crystalline lens becomes convex, and does not bring the rays to a focus n enough, but they meet the retina before they have ne accurately to a focus, and form a confused im- . In this case a pair of convex spectacles aids the stalline lens, and both together cause the image to exactly on the retina. As a piece of mechanism, eye is unequalled for its beauty and perfection, and part of the creation proclaims more distinctly both existence and the wisdom of the Creator.

76. What is essential to distinct vision? Imperfection when the stalline lens is too convex—how remedied—also when not convex ugh—remedy? Perfection of the eye.

Sec. 4. *Of the Microscope.*

177. The Microscope is an optical instrument, designed to aid the eye in the inspection of minute objects. The simplest microscope is a convex lens, like a spectacle glass. This, when applied to small objects, as the letters of a book, renders them both larger and more distinct. When an object is brought nearer and nearer to the eye, we finally reach a point within which vision begins to grow imperfect. That point is called the *limit of distinct vision*. Its distance is about five inches. If the object be brought nearer than this distance, the rays come to the eye too diverging for the lenses of the eye to bring them to a focus soon enough, so as to make their image fall exactly on the retina. Moreover, the rays which proceed from the extreme parts of the object, meet the eye too obliquely to be brought to the same focus with those rays which meet it more directly, and hence contribute only to confuse the picture.

178. We may verify these remarks by bringing gradually towards the eye a printed page with small letters. When the letters are within two or three inches of the eye, they are blended together and nothing is seen distinctly. If we now make a pin-hole through a piece of paper, and look at the same letters through this, we find them rendered far more distinct than before at near distances, and larger than ordinary. Their greater *distinctness* is owing to the exclusion of those oblique rays which, not being brought by the eye to the same focus with the central rays, only tend to confuse the image formed by the latter. As

177. Define the microscope. What is the simplest form of the microscope? Its effect upon the letters of a book. What is the limit of distinct vision? Why do objects appear indistinct when nearer than this?

178. Example in a printed page—Appearance through a pinhole. To what is the greater distictness owing?—The increased brightness?

only the central rays of each pencil can enter so small an orifice, the picture is made up chiefly of the *axes* of all the pencils. These occupy each a separate point in the image, a point where no other rays can reach. The *increased magnitude* of the letters is owing to their being seen nearer than ordinary, and thus under a greater angle, and of course magnified.

179. A convex lens acts much on the same principles, but is still more effectual. It does not *exclude* the oblique rays, but it diminishes their obliquity so much as to enable the eye to bring them to a focus, at the distance of the retina, and thus makes them contribute to the *brightness* of the picture. The object is *magnified*, as before, because it is seen nearer, and consequently under a larger angle, so that the eye can distinctly recognize minute portions of the object, which were before invisible, because they did not occupy a sufficient space on the retina. Lenses have greater magnifying power in proportion as the convexity is greater, and of course the focal distance less. Since the magnifying power of the microscope arises from its enabling us to see objects nearer and under a larger angle, that power is increased in proportion as the focal distance is less than the limit of distinct vision. The latter being five inches, a lens which has a focal distance of one inch, by enabling us to see the object five times nearer, enlarges its length and breadth each five times, and its surface twenty-five times. Lenses have been made capable of affording a distinct image of very minute objects, when their focal distances were only one-sixtieth of an inch. In this case, the magnifying power would be as one-sixtieth to five;

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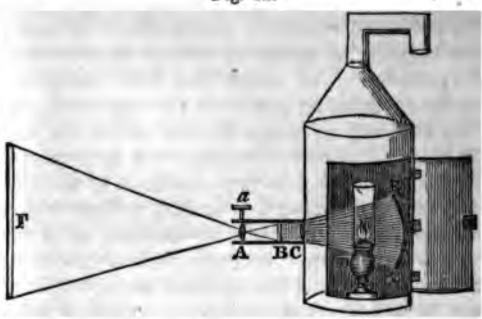
179. Explain the mode in which a convex lens acts. Why it makes objects appear brighter and larger. What lenses have the greatest magnifying power? Power of a lens of one inch focus—of one sixtieth of an inch focus.

or it would magnify the length and breadth each 300 times, and the surface 90,000 times.

180. The *Magic Lantern* and *Solar Microscope* owe their astonishing effects to the magnifying power of a simple lens. When the image so much exceeds the object in magnitude, were the object only enlightened by the common light of day, when it came to be diffused over so great a space, it would be very feeble, and the image would be obscure and perhaps invisible. The two instruments just named, have each an apparatus connected with the magnifying lens, which serves to illuminate the object highly, so that when the rays that proceed from it and form the enlarged image are spread over so great a space, they may still be sufficient to render the image bright and distinctly visible.

Fig. 92.



181. In the Magic Lantern, the illumination is afforded by a lamp, the light of which is reflected from a concave mirror placed behind it, which makes the light on that side return to unite with the direct light

180. To what are the effects of the Magic Lantern and the Solar Microscope owing? Use of all the other parts of the apparatus, except the magnifier?

181. How is the illumination effected in the magic lantern? Describe Fig. 92. What sorts of objects are exhibited?

of the lamp, so that both fall on a large lens which collects them upon the object, thus strongly illuminating it. The foregoing diagram exhibits such a lantern, where the concave mirror behind is seen to reflect back the light to unite with that which proceeds directly from the lamp, so that both fall on the large convex lens at C, which collects them upon the object at B. This is usually painted in transparent colors on glass, and may be a likeness of some individual, small in the picture, but when magnified by the lens, A, and the image thrown on a screen or wall, F, will appear as large as life, and in strong colors; or the objects may be views of the heavenly bodies, which are thus often rendered very striking and interesting; or they may illustrate some department of natural history, as birds, fishes, or plants.

182. The *Solar Microscope* is the same in principle with the Magic Lantern, but the light of the sun instead of that of a lamp is employed to illuminate the object. As a powerful light may thus be commanded, very great magnifiers can be employed; for if the object is highly illuminated, the image will not be feeble or obscure when spread over a great space. By means of this instrument, the eels in vinegar, which are usually so small as to be invisible to the naked eye, may be made to appear six feet in length, and, as their motions as well as dimensions are magnified, they will appear to dart about with surprising velocity. The finest works of art, when exhibited in this instrument, appear exceedingly coarse and imperfect. The eye of a finished cambric needle appears full of rough projections; the blade of a razor looks like a saw; and the finest muslin exhibits threads as large as the cable of a ship. Thus, the small and almost invisible insect

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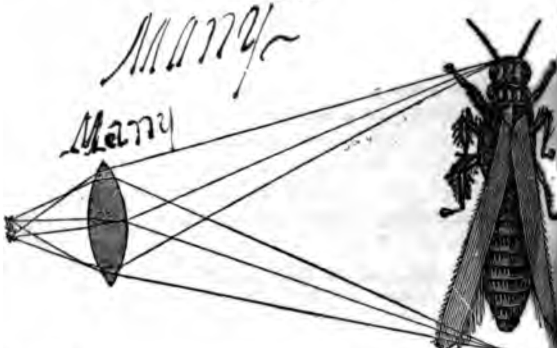
182. Solar Microscope, how it differs from the Magic Lantern—Why greater magnifiers can be used—appearance of the eels in vinegar. How do the works of art appear? How small insects?

represented in figure 93, gives out, when illuminated, so few rays, that when spread over the large surface of the image, the light would be too feeble to render the image visible; but, on strongly illuminating the

Fig. 93.



insect by concentrating upon it a large beam of the sun's light, the image becomes distinct and beautiful, although perhaps a million times as large as the object. Even the minute parts of the insect, as the hairs on the legs, are revealed to us by the microscope.

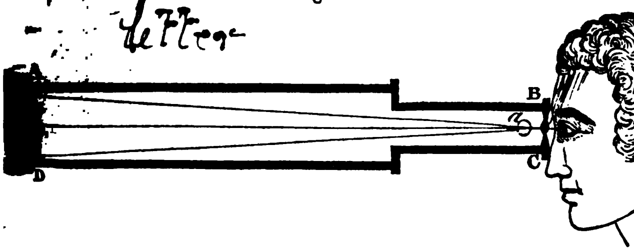
SEC. 5. *Of the Telescope.*

183. The Telescope is an instrument employed for viewing *distant* objects. It aids the eye in two ways; first, by enlarging the angle under which objects are seen, and, secondly, by collecting and conveying to the eye a much larger amount of the light that proceeds from the object, than would enter the naked pupil. *We first form an image of a distant object, the*

183. Define the Telescope. In what two ways does it aid the eye?

moon, *for example, and then magnify that image by a microscope.* The image may be formed either by a concave mirror or a convex lens, for both, as we have seen, form images. Although we cannot go to distant objects, as the moon and planets, so as to view them under the enlarged dimensions in which they would then appear, yet by applying a microscope to the image of one of those bodies, we may make it appear as it would do were we to come much nearer to it. To apply a microscope which magnifies a hundred times, is the same thing as to approach a hundred times nearer to the body.

Fig. 94.



184. Let A B C D represent the tube of the telescope. At the front end, or the end which is directed towards the object, (which we will suppose to be the moon,) is inserted a convex lens, L, which receives the rays of light from the moon, and collects them into the focus at *a*, forming an image of the moon. This image is viewed by a magnifier attached to the end B C. The lens L is called the *object-glass*, and the microscope in B C the *eye-glass*. A few rays of light only from a distant object, as a star, can enter so small

State the main principle of this instrument. How may the image be formed? How it brings objects nearer to us.

184. Describe the telescope as represented in Fig. 94. Point out the object-glass, and the eye-glass. What is the use of a large object-

a space as the pupil of the eye; but a lens one foot in diameter will collect a beam of light equal to a cylinder of the same dimensions, and convey it to the eye. The object glass merely forms an image of the object, but does not magnify; the microscope or eye glass magnifies. By these means, many obscure celestial objects become distinctly visible, which would otherwise be too minute, or not sufficiently luminous, to be seen by us. A telescope like the foregoing, having simply an object glass and an eye glass, inverts objects, since the rays cross each other before they form the image. By employing more lenses, it may be turned back again, so to appear in its natural position, as is usually done in spy glasses, or the smaller telescopes used in the day time. But, since every lens absorbs and extinguishes a certain portion of the light, and since, in viewing the heavenly bodies, we usually wish to save as much of the light as possible, astronomical telescopes are constructed with these two glasses only.

185. Instead of the convex object glass, we may employ the concave mirror to form the image. When the lens is used, the instrument is called a *refracting* telescope; when a concave mirror is used, it is called a *reflecting* telescope. Large reflectors are more easily made than large refractors, since a concave mirror may be made of any size; whereas, it is very difficult to obtain glass that is sufficiently pure for this purpose above a few inches in diameter, although Refractors are more perfect instruments than Reflectors in proportion to their size. Sir William Herschel, a great astronomer of England, of the last century, made a re-

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glass? Which glass collects the light—which magnifies? Can the image be made to appear erect? Why not done in the astronomical telescope?

185. Point out the distinction between refracting and reflecting telescopes. Give an account of Herschel's great telescope.

›cting telescope forty feet in length, with a concave irror more than four feet in diameter. The mirror one weighed nearly a ton. So large and heavy an strument must require a vast deal of machinery to ork it and to keep it steady; and accordingly, the ıme work surrounding it was formed of heavy tim›rs, and resembled the frame of a house. When one the largest of the fixed stars, as Sirius, was enterg the field of this telescope, its approach was an›unced by a bright dawn like that which precedes e rising sun; and when the star itself entered the ›ld, the light was too dazzling to be seen without a ›lored glass to protect the eye.

The telescope has made us acquainted with innuerable worlds, many of which are fitted up in a style far greater magnificence than our own. To the inresting and ennobling study of these, let us next dict our attention.

RUDIMENTS

OF

NATURAL PHILOSOPHY AND ASTRO

PART II.

ASTRONOMY.

CHAPTER I.

DOCTRINE OF THE SPHERE.

DEFINITIONS—DIURNAL REVOLUTIONS.

186. ASTRONOMY *is that science which treat heavenly bodies.* More particularly, its obje teach what is known respecting the Sun, Moo ets, Comets, and Fixed Stars; and also to exp methods by which this knowledge is acquired.

187. Astronomy is the oldest science in the but it was cultivated among the ancients chiefly purposes of Astrology. *Astrology was the art telling future events by the stars.* Its discipl fessed especially to be able to tell from the app of the stars at the time of any one's birth, wha be his course and destiny through life; and, i ing any country, and public events, what w their fate, what revolutions they would underg wars and other calamities they would suffer, good fortune they would experience. Visio

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186. Define Astronomy—What is its object?
187. Antiquity of the science—For what purpose was it

this art was, it nevertheless led to the careful observation and study of the heavenly bodies, and thus laid the foundations of the beautiful temple of modern astronomy.

188. Astronomy is a delightful and interesting study, when clearly understood; but it is very necessary to a clear understanding of it, that the learner should think for himself, and labor to form an idea in his mind of the exact meaning of all the circles, lines, and points of the sphere, as they are successively defined; and if any thing at first appears obscure, he may be assured that by patient thought it will clear up and become easy, and then he will understand the great machinery of the heavens as easily as he does that of a clock. "Patient thought," was the motto of Sir Isaac Newton, the greatest astronomer that ever lived; and no other way has yet been discovered of obtaining a clear knowledge of this sublime science.

189. Let us imagine ourselves standing on a huge ball, (for such is the earth,) in a clear evening. Although the earth is large, compared with man and his works, yet it is very small, compared with the vast extent of the space in which the heavenly bodies move. When we look upward and around us at the starry heavens, we must conceive of ourselves as standing on a small ball, which is encircled by the stars on all sides of it alike, as is represented over the leaf; and we must consider ourselves as bound to the earth by an invisible force, (gravity,) as truly as though we were lashed to it with cords. We are, therefore, in no more danger of falling off, than needles are of fall-

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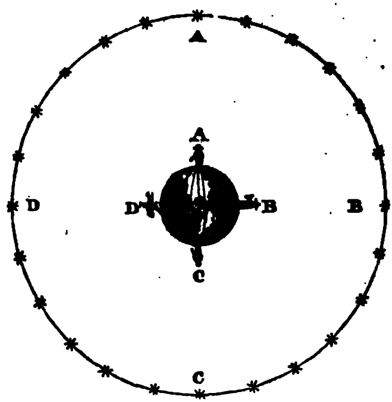
among the ancients? Define astrology. What did its disciples profess? To what good did it lead?

188. What is necessary to a clear understanding of Astronomy? What was the motto of Newton?

189. Where shall we imagine ourselves standing? What is said of the size of the earth? Are persons on the opposite side of the earth in

ing from a magnet or loadstone, when they are attached to it on all sides. We must thus familiarize ourselves to the idea that *up* and *down* are not absolute directions

Fig 95.



in space, but we must endeavor to make it seem to us up in all directions from the center of the earth, and down on all sides towards the center. If people on the opposite side of the globe seem to us to have their heads downwards, we seem to them to have ours in the same position; and, twelve hours hence, we shall be in their situation and they in ours. We see but half the heavens at once, because the earth hides the other part from us; but if we imagine the earth to grow less and less until it dwindles to a point, so as not to obstruct our view in any direction, then we should see ourselves standing in the middle of a vast starry sphere, encompassing us alike on all sides. It

danger of falling off? What idea must we form of *up* and *down?* How should we view the heavens if the earth were so small as not to obstruct our view?

iew of the heavens that the astronomer has in the eye of his mind.

e are apt to bring along with us the first s of childhood; namely, that the sun, moon, re all fixed on the surface of the sky, which e to be a real surface, like that of an arched it it is time now to dismiss such childish d to raise our thoughts to more just views ation. Our eye-sight is so limited that we inguish between different distances, except rate extent; beyond, all objects seem to us e distance, whether they are a hundred or a es off. The termination of this extent of being at equal distances on all sides of us, to stand under a vast dome, which we call The azure color of the sky, when clear, is e than that of the atmosphere itself, which, orless when seen in a small volume, betrays liar to itself when seen through its whole Vere it not for the atmosphere, the sky would ck, and the stars would seem to be so many n a black ground.

r the purpose of determining the relative f places, both on the earth and in the heav- arious circles of the sphere are devised; contemplating the sphere marked up as ar- esentations of it are, we must think of our- tanding on the earth, as on a point in the oundless space, and see, with our mental ure sphere of the heavens, undefaced with ude lines. If we could place ourselves on

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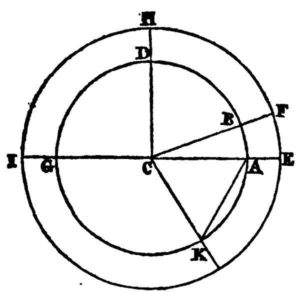
erroneous conceptions are we apt to form in childhood of n and stars? Impossibility of distinguishing different he eye. Under what do we appear to stand? To what or of the sky owing?

hat purpose are the circles of the sphere devised? What efore studying the artificial representations of the sphere? and on one of the stars what should we see? When do any one of the stars, we should see a starry firm over our heads, similar to that we see now.] though we obtain the most correct and agreea well as the most sublime views of the heavenly l when we think of them as they are in nature— scattered at great distances from each other, tl boundless space—yet we cannot make much pı in the science of astronomy, unless we learn tl ficial divisions of the sphere. Let us, therefor turn our attention to these.

192. The definitions of the different lines, and circles, which are used in astronomy, a propositions founded on them, compose the *doct the sphere.* Before these definitions are given, attend to a few particulars respecting the met measuring angles. (See Fig. 96.) A line draw the center to the c ference of a ci called a *radius,* a C B, or C K. A of the circumfer a circle is called as A B, or B D. A is measured by a included betwee radii. Thus, in 96, the angle i between the tw C A and C B, the angle A C measured by the arc A B. Every circle is into 360 equal parts, called *degrees;* and any A B, contains a certain number of degrees, ac

Fig. 96.



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we obtain the most agreeable and sublime views of the hea dies? What else is necessary to our progress?

192. Define the doctrine of the sphere. What is the radius cle—an arc—an angle? Explain by Fig 96. Into how n

to its length. Thus, if an arc, A B, contains 40 degrees, then the opposite angle is said to be an angle of 40 degrees, and to be measured by A B. But this arc is the same part of the smaller circle that E F is of the greater. The arc A B, therefore, contains the same number of degrees as the arc E F, and either may be taken as the measure of the angle A C B. As the whole circle contains 360 degrees, it is evident that the quarter of a circle, or *quadrant*, contains 90 degrees, and that the semi-circle contains 180 degrees.

193. A section of a sphere, cut through in any direction, is a circle. *Great circles* are those which pass through the centre of a sphere, and divide it into two equal hemispheres. *Small circles* are such as do not pass through the center, but divide the sphere into two unequal parts. This distinction may be easily exemplified by cutting an apple first through the center, and then through any other part.* The first section will be a great, and the second a small circle. The *axis* of a circle is a straight line passing through its center at right angles to its plane. If you cut a circle out of pasteboard, and thrust a needle through the center, perpendicularly, it will represent the axis of the circle. The *pole* of a great circle, is the point on the sphere where its axis cuts through the sphere. Every great circle has two poles, each of which is every where 90 degrees from that circle. All great circles of the sphere cut each other in two points, diametrically opposite, and consequently their points of

*It is strongly recommended that young learners be taught to verify the definitions in the manner here proposed.

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grees is every circle divided? Does the arc of a small circle contain the same number of degrees as the corresponding arc of a large circle? How many degrees in a quadrant—in a semi-circle?

193. What figure does any section of a sphere produce? Define *great* circles—*small* circles. How may this distinction be exemplified? Define the axis of a circle—the pole. How many poles has every great circle? How many degrees is the pole from the circumference?

section are 180 degrees apart. Thus, if we cut the apple through the center, in two different directions, we shall find that the points where the circles intersect one another, are directly opposite to each other, and hence the distance between them is half round the apple, and, of course, 180 degrees. A point on the sphere, 90 degrees distant from any great circle, is the *pole* of that circle; and every circle on the globe drawn from the pole to the circumference of any circle, is at *right angles* to it. Such a circle is called a *secondary* of the circle through whose pole it passes.

194. In order to fix the position of any place, either on the surface of the earth or in the heavens, both the earth and the heavens are conceived to be divided into separate portions, by circles which are imagined to cut through them in various ways. The earth, thus intersected, is called the *terrestrial*, and the heavens the *celestial* sphere. The great circles described on the earth, extended to meet the concave sphere of the heavens, become circles of the celestial sphere.

The *Horizon* is the great circle which divides the earth into upper and lower hemispheres, and separates the visible heavens from the invisible. This is the *rational* horizon: the *sensible* horizon is a circle touching the earth at the place of the spectator, and is bounded by the line in which the earth and sky seem to meet. The poles of the horizon are the *zenith* and *nadir*. The zenith is the point directly over our heads; the nadir, that directly under our feet. The plumb line, (such as is formed by suspending a bullet by a string,) coincides with the axis of the horizon, and consequently is directed towards its poles. Every

How does a great circle passing through the pole of another great circle cut the circle? What is such a circle called?

194. How are the earth and heavens conceived to be divided? What is the terrestrial, and what the celestial sphere? How do terrestrial circles become celestial? Define the horizon. Distinguish between the rational and the sensible horizon. Define the zenith and nadir.

n the surface of the earth has its own horizon; e traveller has a new horizon at every step, extending 90 degrees from him in every di-
.

Vertical circles are those which pass through es of the horizon, (the zenith and nadir,) per- ılar to it. The *Meridian* is that vertical circle passes through the north and south points. *rime Vertical*, is that vertical circle which passes ı the east and west points. The *altitude* of a ly body, is its elevation above the horizon, ed on a vertical circle; the *azimuth* of a body istance, measured on the horizon, from the me- to a vertical circle passing through that body; e *amplitude* of a body is its distance, on the ı, north or south of the prime vertical.

In order to make these definitions intelligible niliar, I invite the young learner, who is anx- acquire clear ideas in astronomy, to accompany ne fine evening under the open sky, where we ve an unobstructed view in all directions. A sea would afford the best view for our purpose, evel plain of great extent will do very well. rry the eye all round the line in which the sky to rest upon the earth: this is the horizon. I line with a bullet suspended, and this shows true direction of the axis of the horizon; and upwards in the direction of this line to the ze- irectly over my head, and downwards towards lir. If I mark the position of a star exactly in ıith, as indicated by the position of the plumb-

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what points is the plumb line directed? How many hori- be imagined?
Define vertical circles—the meridian—the prime vertical—al- azimuth—amplitude.
What is proposed in order to make these definitions intelligible liar? What situation would afford the best view?
shall successively denote the por

line, and then turn round and look upward towards the zenith, I shall probably not see the star, because I do not look high enough. Most people will find, if they first fix upon a star as being in the zenith when their faces are towards the south, and then turning round to the north, fix upon another star as near the zenith (without reference to the first,) they will find that the two stars are several degrees apart, the true zenith being half way between them. This arises from the difficulty of looking directly upwards.

197. Having fixed upon the position of the zenith, I will point my finger to it, and carry the finger down to the horizon, repeating the operation a number of times, from the zenith to different points of the horizon: the arcs which my finger may be conceived to trace out on the face of the sky, are arcs of vertical circles. I will now direct my finger towards the north point of the horizon, (having previously ascertained its position by a compass,) and carry it upwards through the zenith, and down to the south point of the horizon: this is the meridian. From the south point, I carry my finger along the horizon, first towards the east, and then towards the west, and I measure off arcs of azimuth. I might do the same from the north point, for azimuth is reckoned east and west from either the north or the south point. I will again direct my finger to the western point of the horizon, and carry it upwards through the zenith to the east point, and I shall trace out the prime vertical. From this, either on the eastern or the western side, if I carry my finger along the horizon, north and south, I shall trace out arcs of amplitude. I will finally fix

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zon—the zenith and nadir. Difficulty of looking directly to the zenith.

197. How to mark out with the finger vertical circles—the meridian—arcs of azumuth—the prime vertical—arcs of amplitude—arcs of altitude?

on a certain bright star, and try to determine it is above the horizon. This will be its altit appears to be about one third of the way horizon to the zenith; then its altitude is 30 But we are apt to estimate the number of near the horizon too large, and near the zenith l, and therefore I look again more attentively, some allowance for this source of error, and the altitude of the star to be about 27 degrees, ourse its zenith distance 63 degrees.

The *Axis of the earth*, is the diameter on which h is conceived to turn in its daily revolution st to east. The same line continued until it ie concave of the heavens, constitutes the *axis elestial sphere.* We will take a large round nd run a knitting-needle through it in the di- of the eye and stem. The part of this that iin the apple, represents the axis of the earth, rolongation (conceived to be continued to the axis of the heavens. We do not suppose re is any such actual line on which the earth ny more than there is in a top on which it ut it is nevertheless convenient to imagine ine, and to represent it by a wire.* The *poles rth* are the extremities of the earth's axis; *of the heavens* are the extremities of the ce- xis.

The *Equator* is a great circle, cutting the axis arth at right angles. The intersection of the the equator with the surface of the earth, con-

nce shows that it is necessary to guard young learners from the posing that our artificial representations of the sphere actually ings as they are in nature.

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fine the axis of the earth—axis of the celestial sphere. How presented by means of an apple? Is there any such actual ich the earth turns? Distinguish between the poles of the the poles of the heavens.

stitutes the *terrestrial*, and its intersection with the concave sphere of the heavens, the *celestial* equator. We have before seen (Art. 195) that every place on the earth has its own horizon. Wherever one stands on the earth, he seems to be in the center of a circle which bounds his view. If he is at the equator, this circle passes through both the poles; or, in other words, at the equator the poles lie in the horizon. Let us imagine ourselves standing there on the 21st of March, when the sun rises due east and sets due west, and appears to move all day in the celestial equator, and let us think how it would seem to see the sun, at noon, directly over our heads, and at night see the north star just glimmering on the north part of the horizon. If we sail northward from the equator, the north star rises just as many degrees above the horizon as we depart from the equator; so that by the time we reach the part of the globe where we live, the north star has risen almost half way to the zenith, and the axis of the sphere which points towards the north star, seems to have changed its place as we have changed ours, and to have risen up so as to make a large angle with the horizon, and the sun no longer mounts to the zenith at noon.

200. Now it is not the earth that has shifted its position; this constantly maintains the same place, and so does the equator and the earth's axis. Our horizon it is that has changed; as we left the equator, a new horizon succeeded at every step, reaching constantly farther and farther beyond the pole of the earth, or dipping constantly more and more below the celestial pole; but being insensible of this change in our hori-

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199. Define the equator. Distinction between the terrestrial and the celestial equator. Where do the poles of the equator lie? How would the sun appear to move to a spectator on the equator? Where would the north star appear? How, when we sail northward from the equator? What apparent change in the earth's axis?

200. What has caused these changes? If we sail quite to the north

the pole it is that seems to rise, and if we were .l quite to the north pole of the earth, the north vould be directly over our heads, and the equator l have sunk quite down to the horizon; and now un, instead of mounting up to the zenith at noon, kims along the horizon all day; and, at night, at ns of the year when the sun is south of the equator, e stars appear to revolve in circles parallel to the on, the circles of revolution continually growing as we look higher and higher, until those stars h are near the zenith scarcely appear to revolve . Those who sail from the equator towards the and see the apparent paths of the sun and stars ge so much, can hardly help believing that those s have been changing their courses; but all these ırances arise merely from the spectator's chang- .is own horizon, that is, constantly having new which cut the axis of the earth at different ːs.

1. The *Latitude* of a place on the earth, is its dis- from the equator, north or south. The *Longi-* of a place is its distance from some standard lian, east or west. The meridian usually taken e standard, is that of the Observatory of Green- , near London; and when we say that the longi- of New York is 74 degrees, we mean that the lian of New York cuts the equator 74 degrees of the point where the meridian of Greenwich it.

2. The *Ecliptic* is the great circle in which the performs its annual revolution around the sun. ısses through the center of the earth and the cen- the sun. It is found by observation, that the does not lie with its axis perpendicular to the

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where will the north star appear? Where the equator? How the sun and stars appear to revolve in their daily progress? *Define the latitude* of a place on the earth—the longitude—from ace *is it reckoned?*

plane of the ecliptic, so as to make the equator coincide with it, but that it is turned about 23½ degrees out of a perpendicular direction, making an angle with the plane itself of 66½ degrees. The equator, therefore, must be turned the same distance out of a coincidence with the ecliptic, the two circles making an angle with each other of 23½ degrees. The *Equinoctial Points*, or *Equinoxes*, are the points where the ecliptic and equator cross each other. The time when the sun crosses the equator in going northward, is called the *vernal*, and in returning southward, the *autumnal* equinox. The vernal equinox occurs about the 21st of March, and the autumnal about the 22d of September. The *Solstitial Points* are the two points of the ecliptic most distant from the equator. The times when the sun comes to them are called the *Solstices*. The summer solstice occurs about the 21st of June, and the winter solstice about the 22d of December.

203. The ecliptic is divided into twelve equal parts, of 30 degrees each, called *Signs*, which, beginning at the vernal equinox, succeed each other in the following order, being each distinguished by characters or symbols, by which the student should be able to recognize the signs to which they severally belong, whenever he meets with them.

1. Aries,	♈	7. Libra,	♎
2. Taurus,	♉	8. Scorpio,	♏
3. Gemini,	♊	9. Sagittarius,	♐
4. Cancer,	♋	10. Capricornus,	♑
5. Leo,	♌	11. Aquarius,	♒
6. Virgo,	♍	12. Pisces.	♓

202. Define the ecliptic. What is the angle of inclination of the ecliptic to the equator? What are the equinoctial points or equinoxes—the vernal equinox—the Autumnal—the solstitial points—the solstices. When do they occur?

203. How is the ecliptic divided? Name the signs of the zodiac and recognize each by its character.

ŀ. The position of a heavenly body is referred its right ascension and declination, as in Geog- we determine the situation of places by their les and longitudes. *Right Ascension* is the an- distance from the vernal equinox, reckoned on the ial equator, as we reckon longitude on the ter- ıl equator, from Greenwich. *Declination* is the ce of a body from the celestial equator, either or south, as latitude is counted from the terres- quator. *Celestial Longitude* is reckoned on the ic from the vernal equinox, and celestial *Latitude* he ecliptic, north or south.

ɔ. *Parallels of Latitude* are small circles paral- the equator. They constantly diminish in size, go from the equator to the pole. The *Tropics* ıe parallels of latitude which pass through the ɔes. The northern tropic is called the tropic of ɘr; the southern, the tropic of Capricorn. The *Circles* are the parallels of latitude that pass gh the poles of the ecliptic, 23½ degrees from oles of the earth. That portion of the earth ı lies between the tropics on either side of the or, is called the *Torrid Zone;* that between the s and the polar circles, the *Temperate Zone;* and etween the polar circles and the poles, the *Fri- 'one.* The *Zodiac* is the part of the celestial e which lies about eight degrees on each side ɘ ecliptic. This portion of the heavens is thus ɘd off by itself because the paths of the planets onfined to it.

ɔ. After having endeavored to form the best idea ın of the circles, and of the foregoing definitions

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Define right ascension—declination—celestial longitude—ce- latitude.

Parallels of latitude. How do they change as we go from the ? The tropics—polar circles—torrid zone—temperate zone— ones—zodiac.

relating to the sphere, we shall derive much aid from inspecting an artificial globe, and seeing how these various particulars are represented there. But every learner, however young, can adopt, with great advantage, the following easy device for himself. To represent the earth, select a large apple, (a melon, when in season, will be found still better.) The eye and the stem of the apple will indicate the position of the two poles of the earth. Applying the thumb and finger of the left hand to the poles, and holding the apple so that the poles may be in a north and south line, turn this little globe from west to east, and its motion will correspond to the daily motion of the earth. Pass a wire or a knitting needle through the poles, and it will represent the *axis* of the sphere. A circle cut round the apple half way between the poles, will be the *equator;* and several other circles cut between the equator and the poles, parallel to the equator, will represent *parallels of latitude;* of which two, drawn 23½ degrees from the equator, will be the *tropics*, and two others, at the same distance from the poles, will be the *polar circles.* The space between the tropics, on both sides of the equator, will be the *torrid zone;* between the tropics and polar circles, the two *temperate zones;* and between the polar circles and the poles, the two *frigid zones.* A great circle cut round the apple, passing through both poles, in a north and south direction, will represent the *meridian*, and several other great circles drawn through the poles, and, of course, perpendicularly to the equator, will be secondaries to the equator, constituting meridians, or *hour circles.* A great circle, cut through the center of the apple, from

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206. After forming as clear an idea as we can of the divisions of the sphere, to what aids shall we resort? How shall we represent the earth—its poles—the daily motion—axis—equator—parallels of latitude—tropics—polar circles—zones—meridians or hour circles—solstices—equinoctial points?

one tropic to the other, would represent the *plane* of the ecliptic, and its intersection with the surface of the apple, would be the *terrestrial* ecliptic. The points where this circle meets the tropics, indicate the position of the *solstices;* and its intersections with the equator, the *equinoctial points.*

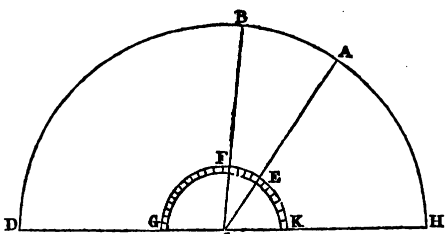
CHAPTER II.

ASTRONOMICAL INSTRUMENTS AND OBSERVATIONS.

TELESCOPE—TRANSIT INSTRUMENT—ASTRONOMICAL CLOCK—SEXTANT.

207. Wherever we are situated on the surface of the earth, we appear to be in the center of a vast sphere, on the concave surface of which all celestial objects are inscribed. If we take any two points on the surface of the sphere, as two stars, for example, and imagine straight lines to be drawn from them to the eye, the angle included between these lines will be measured by the arc of the sky contained between the two

Fig. 97.



points. Thus, if D B H, Fig. 97, represents the con-

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207. How to measure the angular distance between two stars. Illustrate by Fig. 97. Why may we measure the angle on the small circle *G F K?*

cave surface of the sphere, A, B, two points on it, as two stars, and C A, C B, straight lines drawn from the spectator to those points, then the angular distance between them is measured by the arc A B, or the angle A C B. But this angle may be measured on a much smaller circle, G F K, since the arc E F will have the same number of degrees as the arc A B.

208. The simplest mode of taking an angle between two stars, is by means of an arm opening at the joint like the blade of a pen-knife, the end of the arm moving like C E upon the graduated circle G F K. In fact, an instrument constructed on this principle, resembling a carpenter's rule with a folding joint, with a semi-circle attached, constituted the first rude apparatus for measuring the angular distance between two points on the celestial sphere. Thus, the sun's elevation above the horizon might be ascertained by placing one arm of the rule on a level with the horizon, and bringing the edge of the other into a line with the sun's centre. The common surveyor's compass affords a simple example of angular measurement. Here the needle lies in a north and south line, while the circular rim of the compass, when the instrument is level, corresponds to the horizon. Hence, the compass shows the *azimuth* of an object, or how many degrees it is east or west of the meridian. In several astronomical instruments, the telescope and graduated circles are united; the telescope enables us to see minute objects or points, and the graduated circle enables us to measure angular distances from one point to another. The most important astronomical instruments are, the Telescope, the Transit Instrument, the Astronomical Clock, and the Sextant.

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208. What is the simplest mode of taking the angle between two stars? Example of angular measurement by the surveyor's compass. What angle or arc does it measure? Why do some instruments unite the telescope with a graduated circle?

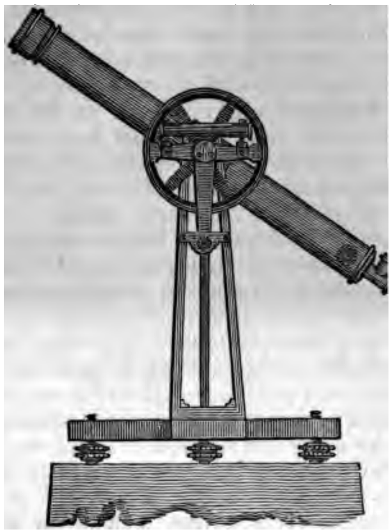
). The *Telescope* has been already described and
nciples explained, (Art. 184.) We have seen that
; the eye in two ways: first, by collecting and
ying to the eye a larger beam of light than would
vise enter it, thus rendering objects more distinct,
nany visible that would otherwise be invisible
ant of sufficient light; and, secondly, by enlarg-
.e angle under which objects are seen, and thus
ng distinctly into view such as are invisible,
scure to the naked eye from their minuteness.
ı the telescope is used by itself, it is for obtain-
:ighter and more enlarged views of the heavenly
s, especially the moon and planets. With the
· kinds of telescopes, we obtain many grand and
sting views of the heavens, and see millions of
s revealed to us that are invisible to the naked

). The *Transit Instrument* (Fig. 98, p. 202,) is a
:ope firmly fixed on a stand, so as to keep it per-
· steady, and permanently placed in the meridian.
›bject of it is to determine when bodies cross the
.ian, or make their *transit* over it; or, in other
;, to show the precise instant when the center of
venly body is on the meridian. The *Astronom-
Clock* is the constant companion of the transit in-
ent. This clock is so regulated as to keep exact
with the stars, which appear to move round the
from east to west once in twenty-four hours, in
quence of the earth's turning on its axis in the
time from west to east. The time occupied in
:omplete revolution of the earth, (which is indi-
by the interval occupied by a star from the me-

How does the telescope aid the eye? When the telescope is
· itself, for what purpose is it? What views do we obtain with
;er kinds of telescopes?
Define the Transit Instrument. What is the object of it?
loes it show? What instrument accompanies it? With what
e *astronomical clock* keep pace? What occasions the apparent

ridian round to the meridian again,) is called
day. It is, as we shall see hereafter, shorte

Fig. 98.



solar day as measured by the return of the s
meridian. The astronomical clock is so reg
to measure the progress of a star, indicating
for every fifteen degrees, and twenty-four hou
whole period of the revolution of a star.
time commences when the vernal equinox
meridian, just as solar time commences whe
is on the meridian.

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movement of the stars from east to west? Define a sidere
how many degrees does an hour correspond? When d
time commence?

211. Anything becomes a measure of time which ·ides duration equally. The celestial equator, there·e, is precisely adapted to this purpose, since, in the ily revolution of the heavens, equal portions of it ss under the meridian in equal times. The only ficulty is, to ascertain the amount of these portions given intervals. Now the astronomical clock shows exactly this amount, for, when regulated to sidereal ne, the hour hand keeps exact pace with the vernal uinox, revolving once on the dial plate of the clock hile the equator turns once by the revolution of the rth. The same is true, also, of all the small circles diurnal revolution; they all turn exactly at the same te as the equator, and a star situated any where be·een the equator and the pole, will move in its diur·l circle along with the clock, in the same manner as ough it were in the equator. Hence, if we note the terval of time between the passage of any two stars, s shown by the clock, we have a measure of the numer of degrees by which they are distant from each ther in right ascension. We see now how easy it to take arcs of right ascension: the transit instruent shows us when a body is on the meridian; the ock indicates how long it is since the vernal equix passed it, which is the right ascension itself. rt. 204.) It also tells us the *difference* of right ascenn between any two bodies, simply by indicating the ference in time between their periods of passing meridian. I observed a star pass the central wire the transit instrument (which was exactly in the ridian) three hours and fifteen minutes of sidereal ne; hence, as one hour equals fifteen degrees, three

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11. How may any thing become a measure of time? Why is the estial equator peculiarly adapted to this purpose? What is the y difficulty? How does the astronomical clock show us what porn of the equator passes under the meridian? Do the parallels of itude turn at the same rate with the equator? How do we measure difference of right ascension between two stars, by means of the

hours and a quarter must have equalle
grees and three quarters, which was t
sion of the star. Two hours and thre
wards, that is, at six hours sidereal t
another star cross the meridian. Its
must have been ninety degress, and c
difference of right ascension of the tw
a quarter degrees.

212. Again, it is easy to take the
body when on the meridian. By decli
recollect, is meant the distance of a
south of the celestial equator. When
ing the meridian line of the transit
point of the meridian towards which
directed at that instant, will be shown
circle of the instrument, and the distar
from the zenith, subtracted from the
place of observation, will give the de
star. We have before seen, that when
the right ascensions and declinations
bodies, we may lay down their relative
map, just as we do those of places
their latitudes and longitudes.

213. The *Sextant* is an instrument
the angular distance of one point from
celestial sphere. It is particularly va
uring celestial arcs at sea, because it
astronomical instruments, affected by
the ship. The principle of the sextan
described as follows: it gives the ang
tween any two objects on the celestia
flecting the image of one of the objec

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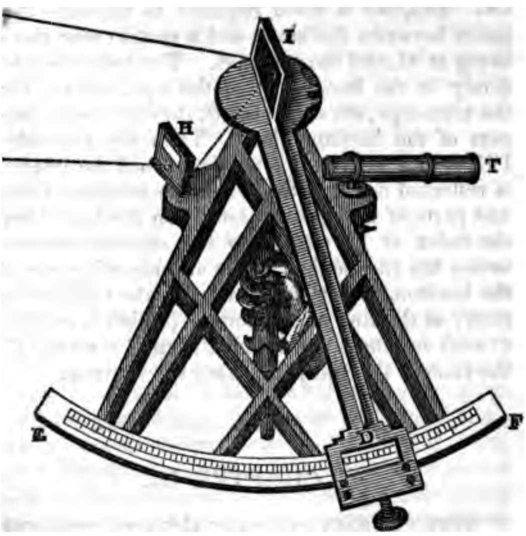
clock? Describe the mode of taking right ascensi
instrument and clock.

212. What is the declination of a body? How
meridian?

213. For what is the Sextant used? For w

with the other object as seen by the naked eye. arc through which the reflector is turned to bring eflected object to coincide with the other object, nes a measure of the angular distance between . The instrument is of a triangular shape, and

Fig. 99.



ade strong and firm by metallic cross-bars. It two small mirrors, I, H, called, respectively, the c glass and the horizon glass, both of which are y fixed perpendicularly to the plane of the in- ent. The index glass is attached to the movable I D, and turns as this is moved along the gradu-

le? State its principle. Describe the Sextant. Point out the glass and the Horizon glass. State the use of the Vernier. De-ated limb, E F. This arm carries a *Vernier* at D, a contrivance which enables us to read off minute parts of the spaces into which the limb is divided. The horizon glass, H, consists of two parts; the upper being transparent or open, so that the eye looking through the telescope, T, can see through it a distant object, as a star, at S, while the lower part is a reflector. Suppose it were required to measure the distance between the moon and a certain star, the moon being at M, and the star at S. The instrument is held firmly in the hand, so that the eye, looking through the telescope, sees the star, S, through the transparent part of the horizon glass. Then the movable arm, I D, is moved from F towards E, until the image of M is reflected down to S; when the number of degrees and parts of a degree reckoned on the limb from F, to the index at D, will show the angular distance between the two bodies. The altitude of the sun above the horizon, at any time, may be taken by looking directly at the line of the horizon (which is well defined at sea) and moving the index from F towards E, until the limb of the sun just grazes the horizon.

CHAPTER III.

TIME. PARALLAX. REFRACTION. TWILIGHT.

SIDEREAL AND SOLAR DAYS—MEAN AND APPARENT TIME—HORIZONTAL PARALLAX—LENGTH OF TWILIGHT IN DIFFERENT COUNTRIES.

214. As time is a measured portion of indefinite duration, any thing or any event which takes place at equal intervals, may become a measure of time. But the great standard of time is the period of the revolution

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scribe the Horizon glass. Describe the mode of taking an observation with the Sextant. How to take the sun's altitude.

f the earth on its axis, which, by the most exact vations, is found to be always the same. The)f the earth's revolution on its axis, as already ined, is called a sidereal day, and is determined e apparent revolution of a star in the heavens. interval is divided into twenty-four *sidereal* hours.

). *Solar* time is reckoned by the apparent revolu- f the sun from noon to noon, that is, from the ian round to the meridian again. Were the sun ıary in the heavens like a fixed star, the time of parent revolution would be equal to the revolu- f the earth on its axis, and the solar and sidereal would be equal. But since the sun passes from to east, in his apparent annual revolution around ırth, three hundred and sixty degrees in three ed and sixty-five days, he moves eastward nearly ree a day. While, therefore, the earth is turn- ıce on its axis, the sun is moving in the same ion, so that when we have come round under the celestial meridian from which we started, we do nd the sun there, but he has moved eastward r a degree, and the earth must perform so much than one complete revolution, before our meri- :uts the sun again. Now, since we move in the ıl revolution, fifteen degrees in sixty minutes, ust pass over one degree in four minutes. It therefore, four minutes for us to *catch up* with ın, after we have made one complete revolution. e, the solar day is almost four minutes longer than dereal; and if we were to reckon the sidereal venty-four hours, we should reckon the solar day y-four hours and four minutes. To suit the pur-

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What may become a measure of time? What is the great d of time?

Distinguish between sidereal and solar time. Why are the solar ıger than the sidereal? How much longer? If we count the y *twenty-four hours*, how long is the sidereal day?

poses of society at large, however, it is found most convenient to reckon the solar day twenty-four hours, and throw the fraction into the sidereal day. Thus,

24h 4m : 24h :: 24h : 23h 56m 4s.

That is, when we reduce twenty-four hours and four minutes to twenty-four hours, the same proportion will require that we reduce the sidereal day from twenty-four hours to twenty-three hours fifty-six minutes four seconds; or, in other words, a sidereal day is such a part of a solar day.

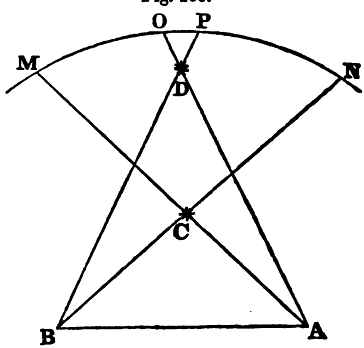
216. The solar days, however, do not always differ from the sidereal by precisely the same fraction, since they are not constantly of the same length. Time, as measured by the sun, is called *apparent* time, and a clock so regulated as always to keep exactly with the sun, is said to keep apparent time. But as the sun in his apparent motion round the earth once a year, goes sometimes faster and sometimes slower, a clock which always keeps with the sun must vary its motion accordingly, making some days longer than others. The *average* length of all the solar days throughout the year, constitutes *Mean Time.* Clocks and watches are commonly regulated to mean time, and therefore do not keep exactly with the sun, but are sometimes faster and sometimes slower than the sun. If one clock is so constructed as to keep exactly with the sun, and another clock is regulated to mean time, the difference between the two clocks at any period is the *equation of time* for that period. The two clocks would differ most about the third of November, when the apparent time is sixteen and a quarter minutes faster than the mean time. But since apparent time is at one time greater and at another less than mean time, the two

216. Do the solar days always differ from the sidereal by the same fraction? What is apparent time? When is a clock said to keep apparent time? What constitutes mean time? How are clocks and watches commonly regulated? What is the equation of time? When would the two clocks differ most, and how much? When would they be together?

must obviously be sometimes equal to each other. This is the case four times a year; namely, April 15th, June 15th, September 1st, and December 24th.

217. As a day is the period of the revolution of the earth on its axis, so a *year* is the period of the revolution of the earth around the sun. This time, which constitutes the astronomical year, has been ascertained with great exactness, and found to be 365d. 5h. 48m. 51sec. The ancients omitted the fraction and reckoned it only 365 days. Their year, therefore, would end about six hours before the sun had completed his apparent revolution in the ecliptic, and, of course, be so much too short. In four years they would disagree a whole day. This is the reason why every fourth year is made to consist of 366 days by reckoning 29 days in February instead of 28. This fourth year the ancients called *Bissextile*—we call it *Leap year.*

Fig. 100.

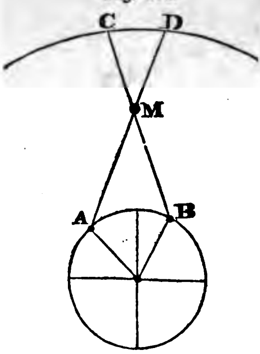


218. PARALLAX *is the apparent change of place which objects undergo by being viewed from different points.*

217. What period is a year? What is its exact length? How long did the ancients reckon it? Explain why every fourth year is reckoned 366 days.

All objects beyond a certain moderate l
us, appear to be projected on the face of t
spectators at some distance from each ot
same body to different points of the sk
M N (Fig. 100) represents the sky, and (
bodies in the atmosphere, a spectator at A
C to M, while one at B would refer it
arc, M N, would measure the angle of t
In the same manner, O P would measure
parallax of the body D. It is evident fro
that nearer objects have a much greater p
those that are remote. Indeed, the fixed
distant, that two spectators a hundred milli
apart would refer a given star to precise
part of the heavens. But the moon is c
near, and her apparent place in the sky
time, is much
parallax. Thu
tator at A, the
appear in the sk
to one at B, it w
at C. Hence, si
body often app
same time diff
ated to spectatc
ent parts of th
tronomers hav
consider the tr
of a body to be
it would appea
if viewed from t
the earth.

Fig. 101.



218. Define parallax. Where do all objects at a c
pear to be projected? How is the same body project
spectators? When have objects a large and when a
What is said of the fixed stars? Of the moon? W
mers consider the true place of a body?

9. The change of place which a body seen in the
:on, by a spectator on the surface of the earth,
d undergo if viewed from the center, is called
:ontal parallax. Although we cannot go to the
er of the earth to view it, yet we can determine
ie aid of geometry where it would appear if seen
the center, and hence we can find the amount of
iorizontal parallax of a heavenly body, as the sun
oon. When we know the horizontal parallax of
ivenly body, we can ascertain its *distance* from us;
he method of doing this cannot be clearly under-
l without some knowledge of trigonomotry.

!0. REFRACTION *is a change of place which the
enly bodies seem to undergo, in consequence of the
tion of their light being altered in passing through
:tmosphere.* As a ray of light traverses the atmos-
e, it is constantly bent more and more, by the re-
ion of the atmosphere, out of its original direction.
an object always appears in that direction in which
ight from it finally comes to the eye. By refrac-
therefore, the heavenly bodies are all made to ap-
higher than they really are, especially when they
near the horizon. The sun and moon, when near
g or setting, are elevated by refraction more than
whole diameter, so that they appear above the
zon both before they have actually risen and after
have set.

!1. TWILIGHT *is that illumination of the sky which
place before sunrise and after sunset,* by means of
:h the day advances and retires by a gradual in-
se or diminution of the light. While the sun is
in eighteen degrees of the horizon, some portion

. What is horizontal parallax? What use is made of horizontal
ax?

. Define refraction. How is a ray of light affected by traversing
mosphere? How does refraction affect the apparent places of
avenly bodies? What is said of the sun and moon?

of its light is conveyed to us by means of th ous reflexions from the atmosphere. At the where the circles of daily motion are perpen the horizon, the sun descends through eigl grees in an hour and twelve minutes. In countries, therefore, the light of day rapidly and as rapidly advances after daybreak in tl ing. At the pole, a constant twilight is enjoy the sun is within eighteen degrees of the hoi cupying nearly two thirds of the half year, direct light of the sun is withdrawn, so that gress from continual day to constant night is ingly gradual. To an inhabitant of one of th rate zones, the twilight is longer in proporti place is nearer the elevated pole.

CHAPTER IV.

THE SUN.

DISTANCE—MAGNITUDE—QUANTITY OF MATTER—SPOT AND CONSTITUTION—REVOLUTIONS—SEASONS

222. The *distance* of the sun from the eartl ninety-five millions of miles. Although, by the sun's horizontal parallax, astronomers h able to find this distance in a way that is entitl fullest confidence, yet such a distance as 95 of miles seems almost incredible. Still small compared with the distance of the fix Let us make an effort to form some idea of distance, which we shall do best by gradual a es to it. We will then begin with so small a

221. Define twilight. How far is the sun below the ho twilight ceases? How is it at the equator—at the poles— middle latitudes?

222. Distance of the sun from the earth. How does it co

s that across the Atlantic ocean, and follow in mind ship, as she leaves the port of New York, and after wenty days' sail reaches Liverpool. Having formed he best idea we can of this distance, we may then eflect, that it would take a ship, moving constantly at he rate of ten miles an hour, more than a thousand ears to reach the sun.

223. The *diameter* of the sun is towards a million f miles; or, more exactly, it is 885,000 miles. One undred and twelve bodies as large as the earth, lying ide by side, would be required to reach across the olar disk; and our ship, sailing at the same rate as efore, would be ten years in passing over the same pace. Immense as is the sun, we can readily understand why it appears no larger than it does, when we eflect that its distance is still more vast. Even large objects on the earth, when seen on a distant eminence, or over a wide expanse of waters, dwindle almost to a point. Could we approach nearer and nearer to the sun, it would constantly expand its volume until it finally filled the whole sky. We could, however, approach but little nearer the sun than we are, without being consumed by his heat. Whenever we come nearer to any fire, the heat rapidly increases, being four times as great at half the distance, and one hundred times as great at one tenth the distance. This fact is expressed by saying, that heat increases as the square of the distance decreases. Our globe is situated at such a distance from the sun, as exactly suits the animal and vegetable kingdoms. Were it either much nearer or more remote, they could not exist, constituted as they are. The intensity of the solar light also follows the

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that of the fixed stars? Effort to form an idea of great distances. How long would it take a ship, moving ten miles an hour, to reach the sun?

223. Diameter of the sun. How many bodies like the earth would it take to reach across the sun? How long the ship to sail over it? Why it appears no larger? How would it appear could we approach nearer and nearer to it? How is the intensity of heat proportioned to

same law. Consequently, were we much nearer t sun than we are, its blaze would be insufferable; were we much farther off, the light would be too d to serve all the purposes of vision.

224. The sun is one million four hundred thous (1,400,000) times as large as the earth; but its m ter is only about one fourth as dense as that of earth, being only a little heavier than water, while average density of the earth is more than five tin that of water. Still, on account of the immense m nitude of the sun, its *quantity of matter* is 354,(times as great as that of the earth. Bodies wo weigh about twenty-eight times as much at the surf of the sun as they do on the earth. Hence, a m weighing three hundred pounds would, if conveye the surface of the sun, weigh 8,400 pounds, or nea three tons and three quarters. A man's limb, weigh forty pounds, would require to lift it a force of 1,1 pounds, which would be beyond the ordinary powe the muscles. At the surface of the earth, a body fa from rest by the force of gravity, in one second, 16 feet; but at the surface of the sun, a body would, the same time, fall through 449 feet.

225. When we look at the sun through a telesco we commonly find on his disk a greater or less nu ber of dark places, called *Solar Spots*. Sometin the sun's disk is quite free from spots, while at ot times we may see a dozen or more distinct clust each containing a great number of spots, some la and some very minute. Occasionally a single spo so large as to be visible to the naked eye, especia

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the distance? Were the earth nearer the sun, what would be consequence? How would its light increase?

224. How much larger is the sun than the earth? How much gre is its quantity of matter? How much more would bodies weigh at sun that at the earth? How much would a man of three hun pounds weigh? Through what space would a body fall in a secon

225. Solar spots—their number—size of the largest—their appe

ı the sun is near the horizon, and the glare of his is taken off. Spots have been seen more than)0 miles in diameter. They move slowly across :entral regions of the sun. As they have all a non motion from day to day across the sun's disk; ey go off on one limb, and, after a certain interval, times come on again on the opposite limb, it is :ed that this apparent motion is imparted to them ı actual revolution of the sun on his axis, which complished in about twenty-five days. This is d the sun's *diurnal* revolution, while his apparent ment about the earth once a year is called his *an*- revolution.

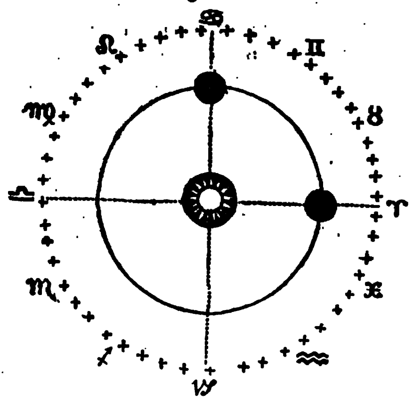
6. We have seen that the apparent revolution of ıeavenly bodies, from east to west, every twenty- hours, is owing to a real revolution of the earth s own axis in the opposite direction. This mo- is very easily understood, resembling, as it does, pinning of a top. We must, however, conceive e top as turning without any visible support, and s resting in the usual manner on a plane. The al motion of the earth around the sun, which gives to the apparent motion of the sun around the earth a year, is somewhat more difficult to understand. n, as the string is pulled, the top is thrown for- . on the floor, we may see it move onward (some- s in a circle) at the same time that it spins on its Let a candle be placed on a table, to represent un, and let these two motions be imagined to be ı to a top around it, and we shall have a case what resembling the actual motions of the earth nd the sun.

ıs—revolution of the sun? Distinction between the diurnal and l revolutions of the sun.

To what is the apparent daily motion of the sun from east to west ? How to conceive of it? How to conceive of the annual mo-

227. When bodies are at such a distance fro other as the earth and sun, a spectator on eithe project the other body upon the face of the sky, seeing it on the opposite side of a great cir hundred and eighty degrees from himself. I

Fig. 102.



102 represent the relative positions of the ea sun, and the firmament of stars. A spectato earth at ♈, (Aries,) would see the sun in the] at ♎, (Libra;) and while the earth was movi ♈ to ♋, (Cancer,) not being conscious of o motion, but observing the sun to shift his a place from ♎ to ♑, (Capricornus,) we shoul bute the change to a real motion in the sun, a that the sun revolves about the earth once a ye not the earth about the sun. Although astro have learned to correct this erroneous impress they still, as a matter of convenience, speak sun's annual motion.

227. How would a spectator on the sun or the earth, p other body? Illustrate by the Figure.

228. In endeavoring to obtain a clear idea of the revolution of the earth around the sun, imagine to yourself a plane (a geometrical plane, having merely length and breadth but no thickness,) passing through the centers of the sun and earth, and extended far beyond the earth until it reaches the firmament of stars. This is the *plane* of the ecliptic; the circlé in which it seems to cut the heavens is the *celestial ecliptic;* and the path desribed by the earth in its revolution around the sun, is the *earth's orbit.* This is to be conceived of as near to the sun compared with the celestial ecliptic, although both are in the same plane. Moreover, we *project* the sun into the celestial ecliptic, because it seems to travel along the face of the starry heavens, since the sun and stars are both so distant that we cannot distinguish between them in this respect, but see them both as if they were situated in the imaginary dome of the sky. If the sun left a visible trace on the face of the sky, the celestial ecliptic would of course be distinctly marked on the celestial sphere, as it is on an artificial globe; and were the celestial equator delineated in a similar manner, we should then see, at a glance, the relative position of these two circles; the points where they intersect one another constituting the *eqinoxes;* the points where they are at the greatest distance asunder, being the *solstices;* and the angle which the two circles make with each other, (23° 28′,) being the *obliquity of the ecliptic.*

229. As the earth traverses every part of her orbit in the course of a year, she will be once at each solstice, and once at each equinox. The best way of

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228. To obtain a clear idea of the revolution of the earth around the sun, what device shall we employ? What is the *plane* of the ecliptic? What the celestial ecliptic? What the earth's orbit? Into what do we project the sun? If the sun left a visible track, what would mark out? If the celestial equator were delineated in the same w what would it mark out? Where would be the equino- stices? *What is the obliquity?*

obtaining a correct idea of her two motions, is to conceive of her as standing still a single day, at some point in her orbit, until she has turned once on her axis, then moving about a degree, and halting again until another diurnal revolution is completed. Let us suppose the earth at the Autumnal equinox, the sun, of course, being at the Vernal equinox. Suppose the earth to stand still in its orbit for twenty-four hours. The revolution of the earth on its axis, in this period from west to east, will make the sun appear to describe a great circle of the heavens from east to west coinciding with the equator. At the end of this time suppose the sun to move northward one degree in its orbit, and to remain there twenty-four hours, in which time the revolution of the earth will make the sun appear to describe another circle from east to west a little north of the equator. Thus, we may conceive of the sun as moving one degree in the northern part of its orbit, every day, for about three months, he will reach the point of the ecliptic farthest from the equator, which point is called the *tropic*, from a Greek word signifying *to turn;* because, after the sun has passed this point, his motion in his orbit carries him continually towards the equator, and therefore he seems to turn about. The same point is also called the *solstice*, from a Latin word signifying *to stand still;* since, when the sun has reached its greatest northern or southern limit, he seems for a short time stationary, with regard to his annual motion, appearing for several days to describe, in his daily motion, the same parallel of latitude.

230. When the sun is at the northern tropic, which happens about the 21st of June, his elevation above the southern horizon at noon is the greatest in the

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229. How to obtain a clear idea of the earth's two motions—describe the process—why is the turning point called the tropic? Why the solstice?

year; and when he is at the southern tropic, about the 21st of December, his elevation at noon is the least in the year.

231. The motion of the earth, in its orbit, is nearly seventy times as great as its greatest motion around its axis. In its revolutions around the sun, the earth moves no less than 1,640,000 miles a day, 68,000 miles an hour, 1100 miles a minute, and 19 miles every second; a velocity sixty times as great as the greatest velocity of a cannon ball. Places on the earth turn with very different degrees of velocity in different latitudes. Those on the equator are carried round at the rate of about 1000 miles an hour. In our latitude, (41° 18′,) the diurnal velocity is about 750 miles an hour. It would seem at first quite incredible that we should be whirled round at so rapid a rate, and yet be entirely insensible of any motion; and much more that we should be going on so swiftly through space, in our circuit around the sun, while all things, when unaffected by local causes, appear to be in such a state of quiescence. Yet we have the most unquestionable evidence of the fact; nor is it difficult to account for it, in consistency with the general state of repose among bodies on the earth, when we reflect that their relative motions, with respect to each other, are not in the least disturbed by any motions which they may have in common. When we are on board a steamboat, we move about in the same manner when the boat is in rapid motion, as when it is lying still; and such would be the case, if it moved steadily a hundred times faster than it does. Were

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230. When does the sun reach the northern tropic? How is then his altitude? When is he at the southern tropic? His altitude then?

231. How much greater is the motion of the earth in its orbit than on its axis? How many miles per day—per hour—per minute—per second? Rates of motion of places in different latitudes? Rate in latitude 41 *degrees and 18 minutes*? Why are we insensible to this great

the earth, however, suddenly to stop its *diurnal* motion, all movable bodies on its surface would be thrown off in tangents to the surface, with velocities proportional to that of their diurnal motion; and were the earth suddenly to halt in its *orbit*, we should be hurled forward into space with inconceivable rapidity.

232. The phenomena of the SEASONS, which we may now explain, depend on two causes; first, the inclination of the earth's axis to the plane of its orbit and, secondly, to the circumstance that the earth's axis always remains parallel to itself. Imagine a candle placed in the center of a large ring of wire, to represent the sun in the center of the earth's orbit, and an apple with a knitting-needle running tnrough it, in the direction of the stem. Run a knife round the central part of the apple, to mark the situation of the equator The circumference of the ring represents the earth's orbit in the plane of the ecliptic. Place the apple so that the equator shall coincide with the wire; then the axis will lie directly across the plane of the ecliptic; that is, at right angles to it. Let the apple be carried quite round the ring, constantly preserving the axis parallel to itself, and the equator all the while coinciding with the wire that represents the orbit Now, since the sun enlightens half the globe at once so the candle, which here represents the sun, will shine on the half of the apple that is turned towards it; and the circle which divides the enlightened from the unenlightened side of the apple, called the *terminator*, will pass through both the poles. If the apple be turned slowly round on its axis, the terminator will pass successively over all places on the earth, giving

motion? Illustrate by a steamboat. What would be the consequence were the earth suddenly to stop its motions?

232. What are the two causes of the change of seasons? How illustrated? How will the appearances be when the apple is so placed that its equator coincides with the wire? Where will it be sun-rise—where sunset?

the appearance of sun-rise to places at which it arrives, and of sun-set to places from which it departs.

233. If, therefore, the earth's axis had been perpendicular to the plane of its orbit, in which case the equator would have coincided with the ecliptic, the diurnal motion of the sun would always have been in the equator, and the days and nights would have been equal all over the globe, and there would have been no change of seasons. To the inhabitants of the equatorial regions, the sun would always have appeared to move in the prime vertical, rising directly in the east, passing through the zenith at noon, and setting in the west. In the polar regions, the sun would always have appeared to revolve in the horizon; while, at any place between the equator and the pole, the course of the sun would have been oblique to the horizon, but always oblique in the same degree. There would have been nothing of those agreeable vicissitudes of the seasons which we now enjoy; but some regions of the earth would have been crowned with perpetual spring; others would have been scorched with a burning sun continually overhead; while extensive regions towards either pole, would have been consigned to everlasting frost and barrenness.

234. In order to simplify the subject, we have just supposed the earth's axis to be perpendicular to the plane of its orbit, making the equator to coincide with the ecliptic; but now, (using the same apparatus as before,) turn the apple out of a perpendicular position a little, (23½ degrees,) then the equator will be turned just the same number of degrees out of a coincidence with the ecliptic. Let the apple be carried

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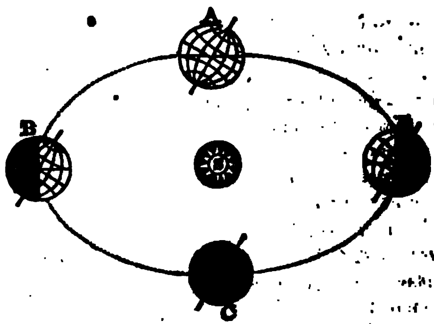
233. Comparative lengths of the days and nights? Appearances to the inhabitants of the equatorial regions? Of the polar regions? Would there have been any change of seasons?

234. Repeat the process with the axis inclined. How far would the equator be turned out of a coincidence with the ecliptic? How does the

around the ring, always holding it inclined at the same angle to the plane of the ring, and always parallel to

Fig. 103.



itself, as in figure 103. We shall find that there are two points, A and C, in the circuit, where the light of the sun (which always enlightens half the globe at once) reaches both poles. These are the points where the celestial equator and ecliptic cut one another, or the equinoxes. When the earth is at either of these points, the sun shines on both poles alike; and if we conceive of the earth, while in this situation, as turning once round on its axis, the apparent diurnal motion of the sun would be the same as it would be, were the earth's axis perpendicular to the plane of the equator. For that day, the earth would appear to revolve in the equator, and the days and nights would be equal all over the globe.

235. If the apple were carried round in the manner supposed, then, at the distance of ninety degrees from the equinoxes, at B and D, the same pole would be turned towards the sun on one side, just as much as it was

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sun then shine with respect to the poles? What will then be the appearances in the diurnal motion?

turned from him on the other. In the former case, the sun's light would reach beyond the pole 23½ degrees, and in the other case, it would fall short of it the same number of degrees. Now imagine, again, the earth turning in the daily revolution, and it will be readily seen how places within 23½ degrees of the enlightened pole, will have continual day, while places within the same distance of the unenlightened pole, will have continual night. By an attentive inspection of figure 103, all these things will be clearly understood. The earth's axis is represented as prolonged, both to show its position, and to indicate that it always remains parallel to itself. On March 21st and September 22d, when the earth is at the equinoxes, the sun shines on both poles alike; while on June 21st and December 24th, when the earth is at the solstices, the sun shines 23½ degrees beyond one pole, and falls the same distance short of the other.

236. Two causes contribute to increase the heat of summer and the cold of winter,—*the changes in the sun's meridian altitudes, and in the lengths of the days.* The higher the sun ascends above the horizon, the more directly his rays fall upon the earth; and their heating power is rapidly increased as they approach a perpendicular direction. The increased length of the day in summer, affects greatly the temperature of places towards the poles, because the inequality between the lengths of the day and night is greater in proportion as we recede from the equator. By the operation of this cause, the heat accumulates so much in summer, that the temperature rises to a higher degree in mid-summer, at places far removed from the equator, than within the torrid zone.

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235. At the distance of 90 degrees from the equinoxes, how would the sun shine with respect to the poles?

236. What two causes contribute to increase the heat of summer and cold of winter? Effect of the sun's altitude—of the increased length of the day?

237. But the temperature of a place is very much by several other causes, as we force and duration of the sun's heat. Firs *tion* of a country above the level of the great influence upon its climate. Elevatec country, even in the torrid zone, often enj agreeable climate in the world. The cold per regions of the atmosphere modifies a the solar heat, so as to give a most delight while the uniformity of temperature exc sudden and excessive changes which are rienced in less favored climes. In asce mountains, situated within the torrid zone, passes, in a short time, through every vai mate, from the most oppressive and sultry soft and balmy air of spring, which again i by the cooler breezes of autumn, and thei verest frosts of winter. A correspondin is seen in the products of the vegetabl While winter reigns on the summit of th its central regions may be encircled with of spring, and its base with the flowers summer. Secondly, the vicinity of the *oc* a great effect to equalize the temperature As the ocean changes its temperature duri much less than the land, it becomes a sourc to neighboring countries in winter, and a cool breezes in summer. Thirdly, the rel *ure* or *dryness* of the atmosphere of a plac importance, in regard to its effects on the tem. A dry air, of ninety degrees, is nc portable as a moist air of eighty degrees. eral principle, a hot and moist air is unhealtl a hot air, when dry, may be very salubrio

237. Effect of elevation—of the vicinity of the ocean· ture and dryness.

CHAPTER V.

THE MOON.

ANCE AND DIAMETER—APPEARANCES TO THE TELESCOPE—MOUNTAINS AND VALLEYS—REVOLUTION—ECLIPSES—TIDES.

38. The Moon is a constant attendant or satellite he earth, revolving around it at the distance of ut 240,000 miles. Her diameter exceeds 2,000 es, (2160.) Her *angular* breadth is about half a ree,—a measure which ought to be remembered, t is common to estimate fire balls, and other sights he sky, by comparing them with the size of the on. The sun's angular diameter is a little greater.

39. When we view the moon through a good telope, the inequalities of her surface appear much re conspicuous than to the naked eye; and by stung them attentively, we see undoubted proofs that face of the moon is very rough and broken, exhibg high mountains and deep valleys, and long mounious ridges. The line which separates the enlighted from the dark part of the moon, is called the *rminator*. This line appears exceedingly *jagged*, licating that it passes over a very broken surface mountains and valleys. Mountains are also indied by the *bright points* and crooked lines, which beyond the terminator, within the unilluminated rt of the moon; for these can be nothing else than vations above the general level, which are enlighted by the sun sooner than the surrounding countries, high mountains on the earth are tipped with the rning light sooner than the countries at their bases. oreover, when these pass the terminator, and come

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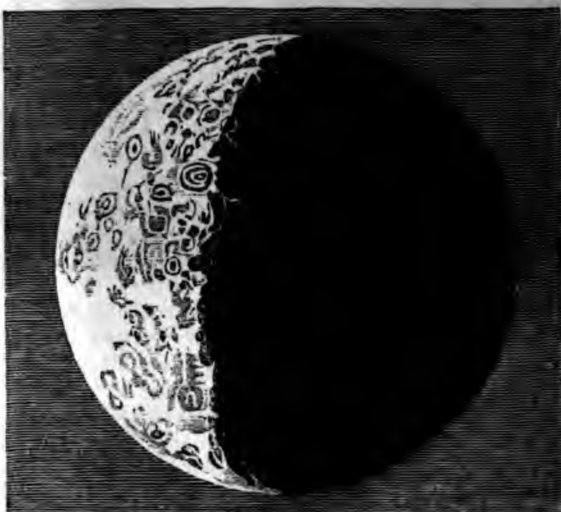
238. Of what is the moon a satellite? Distance from the earth—meter—angular breadth. Why is it important to remember this?
239. How does the moon appear to the telescope? What is the Ternator? How does it appear? What does its unevenness indicate? hat signs of mountains are there in the dark part of the moon? When

within the enlightened part of the disk, they are further recognized as mountains, because they cast shadows opposite the sun, which vary in length as the sun strikes them more or less on a level.

Fig. 104.



240. Spots, also, on the lunar disk, are known to be valleys, because they exhibit the same appearance as is seen when the sun shines into a tea cup, when it strikes it very obliquely. The inside of the cup, opposite to the sun, is illuminated in the form of a crescent,

the terminator passes beyond these, what signs of being mountains do they give?

240. Valleys, how known. Illustrate by the mode in which light

every one may see, who will take the trouble to the experiment,) while the inside, next the sun, ts a deep shadow. Also, if the cup stands on a le, the side farthest from the sun casts a shadow the table outside of the cup. Similar appearances, sented by certain spots in the moon, indicate very arly that they are valleys. Many of them are reg-r circles, and not unfrequently we may see a chain mountains, surrounding a level plain of great ex-t, from the center of which rises a sharp mountain, ting its shadow on the plain within the circle. gure 104 is an accurate representation of the tele-pic appearance of the moon when five days old. will be seen that the terminator is very uneven, and t white points and lines within the unenlightened t of the disk, indicate the tops of mountains and untain ridges. Near the bottom of the terminator, ittle to the left, we see a small circular spot, sur-nded by a high chain of mountains, (as is indicated the shadows they cast,) and in the center of the ley the long shadow of a single mountain thrown m the plain. Just above this valley, we see a ridge mountains, casting uneven shadows opposite to the i, some sharp, like the shadows of mountain peaks. ese appearances are, indeed, rather minute; but we st recollect that they are represented on a very all scale. The most favorable time for viewing the untains and valleys of the moon with a telescope, when she is about seven days old.

241. The full moon does not exhibit the broken as-t so well as the new moon; but we see dark and ht regions intermingled. The dusky places in the on were formerly supposed to consist of water, and

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es into a cup. What shape have many of the valleys? What do sometimes see surrounding the valley? What rising in the center ? Point out mountains and valleys on the diagram?

41. What is said of the telescopic view of the full moon? What

the brighter places, of land; astronomers, how are now of the opinion, that there is no water in moon, but that the dusky parts are extensive pl while the brightest streaks are mountain ridges. I separate place has a distinct name. Thus, a ren able spot near the top of the moon, is called Ty another, Kepler; and another, Copernicus; after ebrated astronomers of these names. The l dusky parts are called seas, as the Sea of Hun the Sea of Clouds, and the Sea of Storms. Son the mountains are estimated as high as five miles, some of the valleys four miles deep.

242. The moon revolves about the earth from to east, once a month, and accompanies the e around the sun once a year. The interval in w she goes through the entire circuit of the heav from any star round to the same star again, is call *sidereal* month, and consists of about $27\frac{1}{4}$ days; bu time which intervenes between one new moon another, is called a *synodical* month, and is comp of $29\frac{1}{2}$ days. A new moon occurs when the sun moon meet in the same part of the heavens; for though the sun is 400 times as distant from us as moon, yet as we project them both upon the face of sky, the moon seems to be pursuing her path an the stars as well as the sun. Now the sun, as we the moon, is travelling eastward, but with a slo pace; the sun moves only about a degree a day, w the moon moves more than thirteen degrees a While the moon, after being with the sun, has b going round the earth in $27\frac{1}{4}$ days, the sun, m

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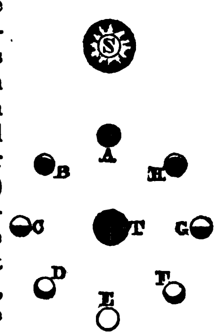
were the dark places in the moon formerly supposed to be? Wh astronomers now consider them? How are places on the moon med? Repeat some of the names. What is the height of some o mountains, and depth of the valleys?

242. Revolutions of the moon. What is a sidereal month? l long is it? What is a synodical month? When does a new m occur? Why is the synodical longer than the sidereal month?

has been going eastward about 27 degrees; so hen the moon returns to the part of the heavens she left the sun, she does not find him there, .es more than two days to catch up with him.

The moon, however, does not pursue precisely ne track with the sun in his apparent annual , though she deviates but little from his path. ıclination of her orbit to the ecliptic is only ive degrees, and, of course, the moon is never 'arther from the ecliptic than that distance, ıe is commonly much nearer to it than that. wo points where the moon's orbit crosses the :, are called her *nodes*. They are the intersec- f the solar and lunar orbits, as the equinoxes are ersections of the equator and ecliptic, and, like :er, are 180 degrees apart.

Fig. 105.



The changes of the moon, ›nly called her *phases*, arise ifferent portions of her en- .ed side being turned towards th at different times. When ›on comes between the earth : sun, her dark side is turned s us, and we lose sight of her hort period, at A, (Fig. 105,) she is said to be in *conjunc-* As soon as she gets a little onjunction, at B, we first e her in the evening sky, form of a crescent,—the ıown appearance of the new When at C, half her enlightened disk is turned to- us, and she is in *quadrature*, or in her first quarter.

Iow many degrees is the moon's orbit inclined to the ecliptic? ıe nodes. How far apart?
Vhence arise the phases of the moon? When is the moon said *conjunction?* When in quadrature? When in opposition?

At D, three-fourths of the disk is illuminated, and at when the earth lies between the sun and the moon, whole disk is enlightened, and she is in *opposition*, time of full moon. In proceeding from oppositio conjunction, or from full to new moon, the illumin portion diminishes in the same way as it increased f conjunction to opposition, being in the last quarte G. Within the first and last quarters, the termin is turned from the sun, and the moon is said to *horned*; but within the second and third quarters, terminator presents its concave side towards the and the moon is said to be *gibbous*.

245. The moon *turns on her axis* in the same t in which she revolves about the earth. This is kn by the moon's always keeping nearly the same towards us, as is indicated by the telescope, wh could not be the case, unless her revolution on axis kept pace with her motion in her orbit. Tak apple to represent the moon; thrust a knitting-ne through it in the direction of the stem, to represent axis, in which case the two eyes of the apple will urally represent the poles. Through the poles, c line around the apple, dividing it into two hemisphe and mark them so as to be readily distinguished f each other. Now place a ball on the table to re sent the earth, and holding the apple by the knitt needle, carry it round the ball, and it will be seen t unless the apple is made to turn about on its axis it is carried around the ball, it will present diffe sides towards the ball; and that, in order to mak always present the same side, it will be necessary make it revolve exactly once on its axis, while i

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What figure has the moon in the first and last quarters? What is second and third?

245. In what time does the moon turn on her axis? How is known? How illustrated by an apple with a knitting-needle? walking round a tree?

going round the circle,—the revolution on its axis keeping exact pace with the motion in its orbit. The same thing will be observed, if we walk around a tree, always keeping the face towards the tree. It will be necessary to turn round on the heel at the same rate as we go forward round the tree.

246. An *Eclipse of the Moon* happens when the moon, in its revolution around the earth, falls into the earth's shadow. An *Eclipse of the Sun* happens when the moon, coming between the earth and the sun, covers either a part or the whole of the solar disk. As the direction of the earth's shadow is, of course, opposite to the sun, the moon can fall into it only when in opposition, or at the time of full moon; and as the moon can come between us and the sun only when in conjunction, or at the time of new moon, it is only then that a solar eclipse can take place. If the moon's orbit lay in the plane of the ecliptic, we should have a solar eclipse at every new moon, and a lunar eclipse at every full moon; but as the moon's orbit is inclined to the plane of the ecliptic about five degrees, the moon may pass by the sun on one side, and the earth's shadow on the other side, without touching either. It is only when, at new moon, the sun happens to be at or near the point where the lunar orbit cuts the plane of the ecliptic, or at one of the *nodes*, that the moon's disk overlaps the sun's, and produces a solar eclipse. Also, when the sun is at or near one of the moon's nodes, the earth's shadow is thrown across the other node, on the opposite side of the heavens, and then, as the moon passes through this node, at the time of opposition, she falls within the shadow, and produces a lunar eclipse.

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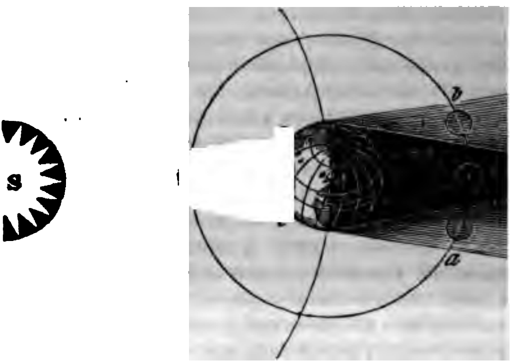
246. When does an eclipse of the moon happen? When an eclipse of the sun? At what age of the moon does it eclipse the sun—and at what age does it suffer eclipse? Why do not eclipses occur at every revolution? At or near what point must the sun be, in order that an eclipse may take *place*?

**247. Figure 106 represents both kinds of (
The shadow of the moon, when in conjun(
represented as just long enough to reach the (**

Fig. 106.



is the case when the moon is at or about he
distance from the earth. In this case, a spe
the earth, situated at the place where the po
shadow touches the earth, would see the s
eclipsed for an instant, while the countries a
a considerable distance, would see only
eclipse, the moon hiding only a part of the su
sheds on such places a partial light, called tl
bra, as is indicated in the figure by the dark
on each side of the moon's shadow. A si
numbra is represented on each side of th
shadow, because, when the moon is approa
shadow, a part of the light of the sun begins
tercepted from her when she reaches this

247. Describe Fig. 106. At what point of the earth woul(
of the sun be total? Where partial? What is this partia
ed? What is said of the moon's penumbra? What occa
nular eclipse?

she receives less and less light from the sun until, when she enters the shadow, his disk is entirely hidden. When the moon is farther from the earth than her average distance, her disk is not large enough to cover the sun's, but a ring of the sun appears all around the moon, constituting an *annular* eclipse.

248. Eclipses of the sun are more frequent than those of the moon. Yet, lunar eclipses, being visible in every part of the hemisphere of the earth in which the moon is above the horizon, while those of the sun are visible only to a small portion of the hemisphere on which the moon's shadow falls, it happens that, for any particular place on the earth, there are seen more eclipses of the moon than of the sun. In any year, the number of eclipses of both luminaries cannot be less than two, nor more than seven. The most usual number is four, and it is very rare to have more than six. A total eclipse of the moon frequently happens at the next full moon after an eclipse of the sun. For, since, in a solar eclipse, the sun is at or near one of the moon's nodes,—that is, is projected to the place in the sky where the moon crosses the ecliptic,—the earth's shadow, which is, of course, directly opposite to the sun, must be at or near the other node, and may not have passed too far from the node before the moon comes round to the opposition and overtakes it.

249. A total eclipse of the sun is one of the most sublime and impressive phenomena of Nature. Among barbarous tribes, it is always looked on with fear and astonishment, and as strongly indicative of the wrath of the gods. When Columbus first discovered Amer-

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248. Which are most frequent, the eclipses of the sun or the moon? Of which are the greatest number visible? What number of both can happen in a single year? What is the most usual number? Why does an eclipse of the moon happen at the next full moon after an eclipse of the sun?

249. What is said of an eclipse of the sun? What is told of Columbus? *Why is a total* eclipse of the sun regarded with so much in-

ica, and was in danger of hostility from the natives he awed them into submission by telling them that the sun would be darkened on a certain day, in token of the anger of the gods at them for their treatment of him. Among cultivated nations, also, a total eclipse of the sun is regarded with great interest, as verifying with astonishing exactness the predictions of astronomers, and evincing the great knowledge they have acquired of the motions of the heavenly bodies, and of the laws by which they are governed. From 1831 to 1838, was a period distinguished for great eclipses of the sun, in which time there were no less than five of the most remarkable character. The next total eclipse of the sun, visible in the United States, will occur on the 7th of August, 1869.

250. Since *Tides* are occasioned by the influence of the sun and moon, a few remarks upon them will conclude the present chapter. By the tides are meant the alternate rising and falling of the waters of the ocean. Its greatest and least elevations are called *high and low water;* its rising and falling are called *flood and ebb;* and the extraordinary high and low tides that occur twice every month, are called *spring* and *neap* tides. It is high water, or low water, on opposite sides of the globe at the same time. If, for example, we have high water at noon, it is also high water to those who live on the meridian below us, where it is midnight. In like manner, low water occurs at the same time on the upper and lower meridian. The average height of the tides, for the whole globe, is about two and a half feet; but their actual height at different places is very various, sometimes being

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terest among cultivated nations? What period was distinguished for great eclipses of the sun? When will the next total eclipse of the sun occur?

250. What are the tides? What is meant by high and low water—flood and ebb—spring and neap? Where is it high water and where

scarcely perceptible, and sometimes rising to sixty or seventy feet. In the Bay of Fundy, where the tide rises 70 feet, it comes in a mighty wave, seen thirty miles off, and roaring with a loud noise.

251. Tides are caused by the unequal attraction of the sun and moon upon different parts of the earth. We shall attend hereafter more particularly to the subject of universal gravitation, by which all bodies, or masses of matter, attract all other bodies, each according to its weight, when they act on a body at the same distance; but when at different distances, the force increases rapidly as the distance is diminished, so that the force of attraction is four times as great for half the distance, one hundred times as great for one tenth the distance, and, universally, the force increases in proportion as the square of the distance diminishes. Such a force as this is exerted by the moon and by the sun upon the earth, and causes the tides. As the sun has vastly more matter than the moon, it would raise a higher tide than the moon, were it not so much further off. This latter circumstance gives the advantage to the moon, which has three times as much influence as the sun in raising the tides. If these bodies, one or both of them, acted *equally* on all parts of the earth, they would draw all parts towards them alike, but would not at all disturb the mutual relation of the parts to each other, and, of course, would raise no tide. But the sun or moon attracts the water on the side nearest to it more than the water more remote, and thus raises them above the general level, forming the *tide wave*, which accompanies the moon in her daily revolution around the earth. It is not dif-

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low water at the same time? Average height of the tides for the whole globe? What is said of their actual height at different places? How high does the tide rise in the Bay of Fundy?

251. By what are tides caused? What force is exerted by the sun and moon upon the earth? Why does not the sun raise a greater tide than the moon? How does the sun's greater distance give the

ficult to see how the tide is thus raised on the side of the meridian nearest to the moon; but it may not be so clear why a tide should at the same time be raised on the opposite meridian. The reason of this is, that the waters farthest from the moon, being attracted less than those that are nearer, and less than the solid earth, are *left behind*, or appear to rise in a direction opposite to the center of the earth. Hence, we have two tides every twenty-four hours,—one when the moon passes the upper meridian, and one when she passes the lower. Each, however, is about fifty minutes later to-day than yesterday, for the moon comes to the meridian so much later on each following day.

252. Were it not for the impediments which prevent the force from producing its full effects, we might expect to see the great tide wave always directly beneath the moon, attending it regularly around the globe. But the inertia of the waters prevents their instantly obeying the moon's attraction, and the friction of the waters on the bottom of the ocean still further retards its progress. It is not, therefore, until several hours after the moon has passed the meridian of a place, that it is high tide at that place.

253. The sun has an action similar to that of the moon, but only *one-third* as great. It is not that the moon actually exerts a greater force of attraction upon the earth than the sun does, that her influence in raising the tides exceeds that of the sun. She, in fact, exerts much less force. But, being so near, the *difference* of her attraction on different parts of the earth is greater than the difference of the sun's attraction; for the sun is so far off, that the diameter of the earth

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advantage to the moon? Why is it high tide on opposite sides of the earth at the same time? How much later is the high tide of to-day than that of yesterday?

252. Why is it not high tide when the moon is on the meridian?

253. How much less is the action of the sun in raising the tides than that of the moon? Why has the moon so much greater power?

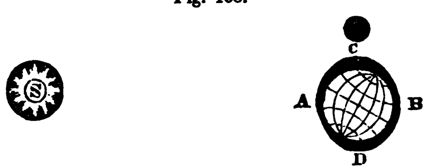
bears but a small proportion to the distance, and therefore the force exerted by the sun is more nearly equal on all parts of the earth, and we must bear in mind that the tides are owing, not to the amount of the force of attraction, but to the difference of the forces exerted on different parts of the earth.

254. As the sun and moon both contribute to raise the tides, and as they sometimes act together and sometimes in opposition to each other, so corresponding variations occur in the height of the tides. The *spring tides*, or those which rise to an unusual height

Fig. 107.

twice a month, are produced by the sun and moon's acting together; and the *neap tides*, or those which are unusually low twice a month, are produced by the sun and moon's acting in opposition to each other. The spring tides occur when the sun and moon act in the same line, as is the case both at new and full

Fig. 108.



moon; and the neap tides when the two luminaries act in directions at right angles to each other, as is the

254. Explain the spring tides—also the neap tides. Illustrate by the *figures*.

case when the moon is in quadrature. T
ation, in each case, will be clearly under
specting figures 107 and 108.

Figure 107 shows the situation of the t
ries when they act together at new moon
ters are elevated both on the same side o
as the attracting bodies at A, and also on t
side, at B. If we now conceive the moon
its place to B, when it would be full moon,
would still have the same elongated figure
of the two bodies, while at places 90° dista
D, it would be low water. Again, in figu
moon being in quadrature at C, the two
bodies act in opposition to each other, the
a tide at A and B, while the moon raises a
tide at C and D. Hence, the high tide h
moon, and the low tide at places 90° distan
less than ordinary.

255. The largest lakes and inland seas h
ceptible tides. This is asserted by all w
specting the Caspian and Black Seas; and
is found to be true of the largest of the No
can lakes, Lake Superior. Although the
tracts of water appear large, when taken
selves, yet they occupy but small portio
surface of the globe, as will be evident on s
small a space they occupy on the artificial
that the attraction of the sun and moon is ne
on all parts of such sea or lake. But it i
quality of attraction on different parts that
the tides.

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255. Why have lakes and inland seas no tides?

CHAPTER V.

THE PLANETS.

GENERAL VIEW—INFERIOR PLANETS—SUPERIOR PLANETS—PLANETARY MOTIONS.

SECTION 1. *General View of the Planets.*

256. The name planet is derived from a Greek word which signifies a *wanderer*, and is applied to this class of bodies, because they shift their positions in the heavens, whereas the fixed stars constantly maintain the same places with respect to each other. The planets known from a high antiquity are, Mercury, Venus, Earth, Mars, Jupiter, and Saturn. To these, in 1781, was added Uranus, (or Herschel, as it is sometimes called, from the name of the discoverer,) and, as late as the commencement of the present century, four more were added, namely, Ceres, Pallas, Juno, and Vesta. All these are called *primary* planets. Several of them have one or more attendants, or *satellites*, which revolve around them, as they revolve around the sun. The earth has one satellite, namely, the moon; Jupiter has four; Saturn, seven; and Uranus, six. Mercury, Venus, and Mars, are without satellites. The same is the case with the four new planets, or *asteroids*, as they are sometimes called. The whole number of planets, therefore, are twenty-nine, namely, eleven primary, and eighteen secondary planets.

257. Mercury and Venus are called *Inferior* planets, because they have their orbits nearer to the sun than that of the earth; while all the others, being more distant from the sun than the earth is, are called *Su-*

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256. Whence the name planet? What planets have been known from a high antiquity? What have been added to these? What is said of the satellites? What is the whole number of planets?

257. Why are Mercury and Venus called Inferior planets? Why the others Superior planets?

perior planets. Let us now compare the planet one another, in regard to their distances from th their magnitudes, and their times of revolution.

258. *Distances from the sun, in miles.*

1.	Mercury,	☿	37,000,000.
2.	Venus,	♀	68,000,000.
3.	Earth,	⊕	95,000,000.
4.	Mars,	♂	142,000,000.
5.	Vesta,	⚶	225,000,000.
6.	Juno,	⚵	
7.	Ceres,	⚳	261,000,000.
8.	Pallas,	⚴	
9.	Jupiter,	♃	485,000,000.
10.	Saturn,	♄	490,000,000.
11.	Uranus,	♅	1800,000,000.

The dimensions of the planetary system a from this table to be vast, comprehending a space thirty-six hundred millions of miles in di A rail-way car, travelling constantly at the twenty miles an hour, would require more than thousand years to cross the orbit of Uranus.

259. *Magnitudes.*

	Diameter.		Diamete
1. Mercury,	3140.	5. Ceres,	16
2. Venus,	7700.	6. Jupiter,	89,00
3. Earth,	7912.	7. Saturn,	79,00
4. Mars,	4200.	8. Uranus,	35,00

We perceive that there is a great diversity the planets, in regard to size. While Venus, a rior planet, is nine-tenths as large as the earth a *superior* planet, is only one-seventh, while is twelve hundred and eighty-one times as

*The magnitudes are proportioned to the *cubes* of the diameters.

258. Repeat the table of distances. What is said of th sions of the planetary system ? How long would a railway crossing the orbit of Uranus ?

259. Repeat the table of magnitudes. What is said of the

lthough several of the planets, when nearest to us, ppear brilliant and large when compared with most f the fixed stars, yet the angle under which they are een is very small, that of Venus, the greatest of all, ever exceeding about one minute, which is less than ne-thirtieth the apparent diameter of the sun or moon.* upiter, also, by his superior brightness, sometimes akes a striking figure among the stars; yet his greatst apparent diameter is less than one-fortieth that of e sun.

260. *Periodic Times.*

Mercury,	3 months.	Ceres,	4⅗ years.
Venus,	7½ "	Jupiter,	12 "
Earth,	1 year.	Saturn,	29 "
Mars,	2 years.	Uranus,	84 "

We perceive that the planets nearest the sun move ost rapidly. Mercury performs nearly three hunred and fifty revolutions while Uranus performs one. he apparent progress of the most distant planets round the sun is exceedingly slow. Uranus advances nly a little more than four degrees in a whole year; that we find this planet occupying the same sign, nd of course remaining nearly in the same part of e heavens, for several years in succession.

SEC. 2. *Of the Inferior Planets.*

261. Mercury and Venus have their orbits so far ithin that of the earth, that they appear to us as atndants upon the sun. Both planets appear either in e west a little after sunset, or in the east a little be-

*In every estimation of angular breadths or distances, it is convenient to ar in mind that the angular breadth of the sun or moon is about half a gree.

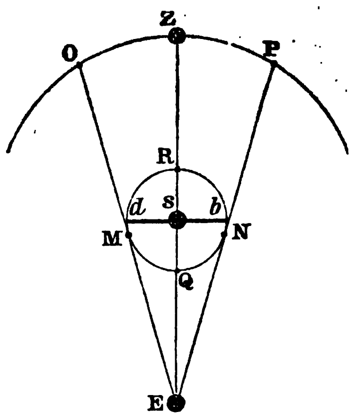
regard to size? What of the angular diameter of the planets? low do the largest compare with the sun or moon?

260. Repeat the table of periodic times. What is said of the planets nearest the sun? What of those most distant?

261. *How do Mercury* and Venus appear with respect to the sun?

fore sunrise. In high latitudes, where the twilight is long, Mercury can seldom be seen with the naked eye, and then only when its angular distance from the sun is greatest. In our latitude, we can usually catch a glimpse of this planet for several evenings and mornings, if we will watch the time (usually given in the almanac) when it is at its greatest elongations from the sun. It, however, soon runs back again to the sun. The reason of this will be plain from the following diagram. Let S represent the sun, E the earth,

Fig. 109.



M Q N R the orbit of Mercury, O Z P an arc of the heavens. Then, since we refer all distant bodies in the sky to the same concave sphere, we should see the sun at Z, in the heavens, and when the planet was at R or Q, we should see it close by the sun, and when

What of Mercury in high latitudes? What in our latitude? When do we catch a glimpse of it? Explain the reason of this from the figure.

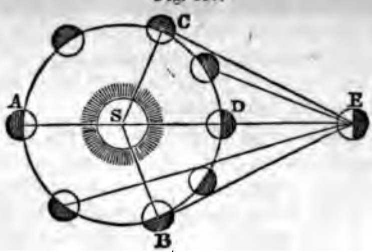
it was at its greatest elongation, at M or N, we should see it at O or P, when its angular distance from the sun would be measured by the arc O Z or P Z. Suppose Mercury comes into view at M, its greatest eastern elongation; as it passes on to Q, its inferior conjunction, it appears to move in the sky backwards, or contrary to the order of the signs, from O to Z; and it continues its backward motion from M to N, or apparently from O to P. But now from N, its greatest western elongation, through R, its superior conjunction, to M, its greatest eastern elongation, its apparent motion is direct. Then, the planet is said to be in its *superior conjunction.* The inferior planets, Mercury and Venus, appear to run backwards and forwards across the sun, Mercury receding so little from that luminary as almost always to be lost in his beams. Venus, however, moves in a larger orbit, and recedes so far from the sun, on both sides, as often to remain a long time in the evening or morning sky, always immediately following or preceding the sun, and hence called the evening and morning star.

262. When an inferior planet is near its greatest elongation, on either side, it presents to us, when viewed with the telescope, half its enlightened disk, appearing to the telescope like the moon in one of her quarters. While passing from the eastern to the western elongation, through the inferior conjunction, the enlightened portion grows less and less, taking the crescent form, like the old of the moon, until it arrives at the inferior conjunction, when it presents the entire dark side towards us. Soon after passing the conjunction, it appears like the new moon, and increases to the first quarter, at the greatest western elongation. When passing through the superior conjunction, the

262. How does an inferior planet appear when at its greatest elongation? How when between that and the inferior conjunction? How towards the superior conjunction? In what respects do they resemble

other side of the sun, the enlightened part co increases, and becomes like the full moon in perior conjunction, after which the enlightened decreases. The phases of Mercury and Venu fore, as seen in the telescope, resemble the of the moon. In some respects, however, the ances do not correspond to those of the mc since, when full, they are in the part of the or remote from us, they appear then much smal when on the side of the inferior conjuncti their nearness to the sun, when full, also preve being seen except in the day time, and then t invisible to the naked eye, because their ligh in that of the sun. Hence, these planets brightest when a little less than half their enli

Fig. 110.



sides are turned towards us, (being then just their greatest elongation on either side,) sinc greater nearness to us more than compensates f ing in view a less portion of the enlightened will be seen by the accompanying diagram.

263. Mercury and Venus both revolve on the in nearly the same time with the earth, and therefore, similar days and nights. Mercury

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the changes of the moon? How do they differ? At what the inferior planets appear brightest?

almost all its peculiarities to its nearness to the sun. Its light and heat derived from the sun are estimated to be nearly seven times as great as ours, and the sun would appear to an inhabitant of Mercury seven times as large as it does to us. The motion of Mercury, in his revolution round the sun, is swifter than that of any other planet, being more than 100,000 miles every hour; whereas, that of the earth is less than 70,000. Eighteen hundred miles every minute,—crossing the Atlantic ocean in less than two minutes,—this is a velocity of which we can form but very inadequate conceptions.

264. Every time Mercury and Venus come to their inferior conjunction, they would eclipse the sun, if their orbits coincided with the earth's orbit, or both were in the same plane; as we should have a solar eclipse at every new moon, if the moon's orbit were in the same plane with the earth's. As, however, the orbits of these planets are inclined to the ecliptic, they are not seen on the sun's disk except when the conjunction takes place at one of their nodes. They then pass over the sun, each in a round black spot, and the phenomenon is called a *Transit*. Transits of Mercury and Venus occur but seldom, but are regarded with the highest interest by astronomers, that of Venus, in particular; for, by observing it at distant points on the earth, materials are obtained for finding the sun's horizontal parallax, which enables astronomers to calculate the distance of the sun from the earth. (See Art. 219.) In the transits of Venus, in 1761 and 1769, several European governments fitted out expensive expeditions to parts of the earth remote from each other. For this purpose, the celebrated

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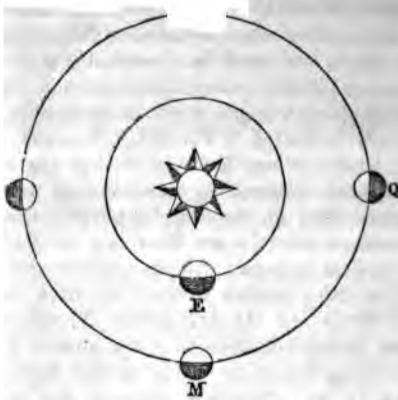
263. In what time do Mercury and Venus revolve on their axes? To what does Mercury owe its peculiarities? Explain his swiftness of motion.

264. Why do not Mercury and Venus eclipse the sun at every inferior conjunction? What is a transit? Why regarded with so great

Captai k, in 1769, went to the South Pacific Ocean, bserved the transit of Venus at the Island of Ota (Tahiti,) while others went to Lapland for the purpose, and others, still, to many other parts o globe. The next transit of Venus will happe 874.

Sec *f the Superior Planets.*

265 the planets, except Mercury and Venus, have t ne sun than the earth's orbit. erior conjunction with the su the moon when full; but as stant from the sun than



the earth is, they can never come into inferior conjunction. This will be plain from the foregoing dia-

interest? What is said of the transits of Venus in 1761 and 1769? When will the next transit of Venus happen?

gram. Let the earth be at E, and a superior planet, as Mars, in different parts of his orbit, M Q M′. At M′, the planet would be seen in the same part of the heavens with the sun, rising and setting at the same time with him, and would therefore be in conjunction; but being the other side of the sun, it would, of course, be a *superior* conjunction. At Q, the planet would appear in quadrature, and at M, in opposition, rising when the sun sets, like the full moon.

266. The superior planets, however, do not, like the inferior, undergo the same changes as the moon, but, with the exception of Mars, always present to the telescope their disks fully enlightened; for, if we viewed them from the sun, we should have the whole enlightened side turned constantly towards us; and so small is our own distance from the sun, compared with that of Jupiter, Saturn, or Uranus, that we view them nearly as though we stood on the sun. Mars, being nearer the earth, does in fact change his figure slightly; for, when seen in quadrature, at Q, a small part of the enlightened hemisphere is concealed from us, and the planet appears gibbous, like the moon when a little past the full. The superior planets, however, undergo considerable changes in apparent magnitude and brightness, being at one time much nearer to us than at another. Thus, in figure 111, Mars, when at M, in opposition, is nearer the earth than at M′, in superior conjunction, by the whole diameter of the earth's orbit,—a space of about 190,000,000 miles. Hence, when this planet is in opposition, rising soon after the sun sets, it often surprises us by its unusual splendor, which appears more

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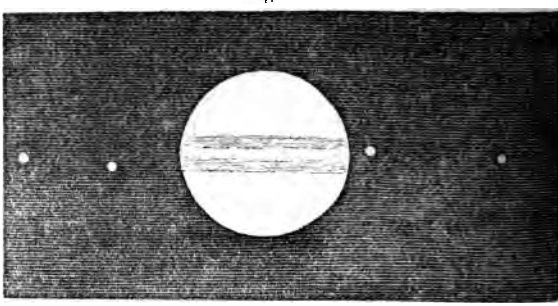
265. What are superior planets? How do they differ from the inferior? Explain their conjunction and opposition by the figure.

266. Have the superior planets any phases? What is said of the phases of Mars? What changes of apparent magnitude do the superior planets undergo? Explain the cause of these.

striking on account of its fiery red color. All the other planets, likewise, appear finest when in opposition, although the remoter planets are less altered than those that are nearer to us.

267. Jupiter is distinguished from all the other planets by his great magnitude. His diameter is 89,000 miles, and his volume 1281 times that of the earth. He revolves on his axis once in about ten hours, giving to places near his equator a motion

Fig. 112.



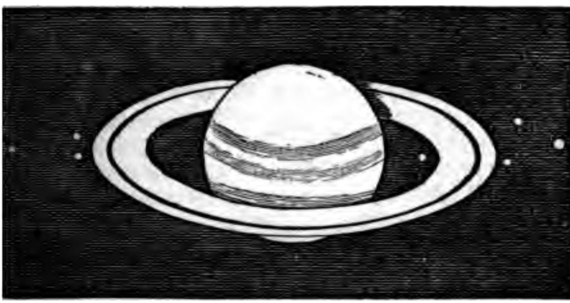
twenty-seven times as swift as on the earth. It will be recollected, also, that the distance of Jupiter from the sun is 485,000,000 miles, and that his revolution around the sun occupies twelve years; so that every thing belonging to this planet is on a grand scale. The view of Jupiter through a good telescope, is one of the most splendid and interesting sights in astronomy. The disk expands into a large and bright orb, like the full moon; across the disk, arranged in parallel stripes, are several dusky bands, called *belts;* and

267. By what is Jupiter distinguished from all the other planets? His diameter—volume—distance from the sun? View of Jupiter through a good telescope? Appearance of his disk, belts and satellites?

four bright satellites, or moons, constantly varying their positions, add another feature of peculiar magnificence.

268. SATURN has also within itself a system full of grandeur. Next to Jupiter, it is the largest of the planets, being 79,000 miles in diameter, or about 1000 times as large as the earth. It has, likewise, belts on its surface, though less distinct than those of Jupiter.

Fig. 113.

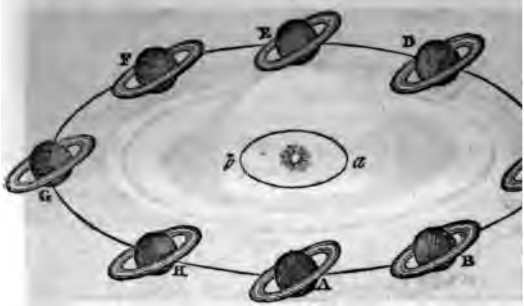


But the great peculiarity of Saturn is its *Ring*, a broad wheel, encompassing the planet at a great distance from it. What appears to be a single ring, when viewed with a small telescope, is found, when examined by powerful telescopes, to consist of two rings, separated from each other by a dark line of the sky, seen between them. Although the division of the rings appears to us, on account of our immense distance, as only a fine line, yet it is in reality an interval of not less than 1,800 miles ; and, although we see in the telescope but a small speck of sky between the planet and the ring, yet it is really a space 20,000 miles

268. Saturn compared with Jupiter—diameter—volume—belts—*Ring*—what is said of this ? Distance between the rings ? Breadth

broad. The breadth of the inner wheel is
miles, and that of the outer, 10,500 miles; so t
entire diameter of the outer ring, from outside
side, is 179,000 miles. These rings are so f
the body of the planet, that an inhabitant of tha
would not take them for appendages to his own
but would view them as magnificent arches on t
of the starry heavens.

Fig. 114



269. Saturn's ring, in its revolution with the around the sun once in about thirty years, keeps parallel to itself, as is represented in the nexed diagram, where the small circle, *a b*, earth's orbit, and Saturn is exhibited in eight di positions in his orbit. If we hold a circle, as a of coin, directly before the eye, we see the enti cle; but if we hold it obliquely, it appears an e and if we turn it round until we see it edgewi ellipse grows constantly narrower and narrower when the edge is towards us, we see nothing

of each wheel? Entire diameter of the outer ring? What i the appearance of the rings from the planet?

269. What position does the ring keep in its revolution ar sun? Describe Fig. 114. Into what figures is a circle project

line. If the learner obtains a clear idea of these appearances, he will easily understand the different appearances of Saturn's ring. In two points of the revolution around the sun, at A and E, the edge is presented to us, and we see the ring only as a fine line, or, perhaps lose sight of it altogether. After passing this point, from B to C, we see more and more of the ellipse, until, in about seven years it arrives at C, when it appears quite broad, as represented in figure 114. Then it gradually closes again for seven years more, and dwindles into a line at E.

270. Saturn is attended by seven *satellites*. Although they are bodies of considerable size, yet, on account of their immense distance from us, they appear exceedingly minute, and require superior telescopes to see them at all. It is accounted a good telescope which will give a distinct view of even three of the satellites of Saturn, and the whole seven can be seen only by the most powerful telescopes in the world.

271. Uranus is also a large body, being 35,000 miles in diameter; but being 1800,000,000 miles off, it is scarcely seen except by the telescope, and would hardly be distinguished from a fixed star, if it were not seen to have the motions of a planet. In the most powerful telescopes, however, it exhibits more of the character of a planet. Herschel saw, as he supposed, six satellites belonging to this planet, but only two are commonly visible to the best telescopes. So distant is this planet, that the sun himself would appear from it 400 times less than he does to us, and it receives from him light and heat proportionally feeble.

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seen in different positions? In what points is the edge presented to us? When does it appear broadest?

270. How many satellites has Saturn? How do they appear to the telescope? What power does it require to see them?

271. Uranus—his diameter—distance from the sun—appearance in the telescope—*number of satellites*? How would the sun appear from *Uranus*?

272. The NEW PLANETS, OF ASTEROIDS, Ceres, Pallas, Juno, and Vesta, were unknown until the commencement of the present century. They are so small as to be invisible to the naked eye, but are seen by telescopes of moderate power. They lie near together in the large space between the orbits of Mars and Jupiter, at an average distance from the sun of about 250,000,000 miles.

SEC. 4. *Of the Planetary Motions.*

273. The planets all revolve around the sun in the same direction, from west to east, and pursue nearly the same path in the heavens. Mercury wanders farthest from the general track, but he is never seen farther than about seven degrees from the ecliptic. The others, with the exception of the Asteroids, are always seen close in the neighborhood of the ecliptic, and we never need to look in any other part of the sky for a planet, than in the region of the sun's apparent path in the heavens.

274. If we could stand on the sun and view the planets move round it, their motions would appear very simple. We should see them one after another, pursuing their way along the great highway of the heavens, the zodiac, rolling around the sun as the moon does around the earth, though with very different degrees of speed, those near the sun moving with far more rapidity than those more remote, often overtaking them, and passing rapidly by them. Mercury, especially, comes up with and passes Jupiter, Saturn, and Uranus, a great number of times while they are

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272. What is said of the New Planets—their discovery—size—position in the solar system—distance from the sun?

273. Planetary motions—through what part of the heavens—which wanders farthest from the ecliptic?

274. If we could view the planets from the sun, how would they appear to move? In what orbits, and with what different degrees of speed?

making their tardy circuit around the sun. To a spectator thus situated, the planets would all appear to move around him in great circles, such being their projections on the face of the sky. They are, however, not perfect circles, but are a little shorter in one direction than the other, forming an oval or ellipse.

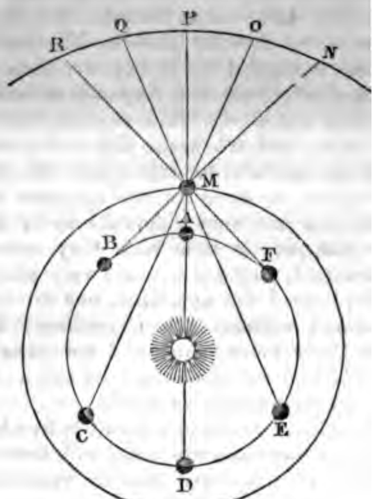
275. Such would be the appearances of the planetary motions if viewed from the center of their motions, that is, at the sun, and such they are in fact. But two causes operate to make the motions of the planets appear very different from what they really are; first, we view them out of the center of their motions, and, secondly, we are ourselves in motion. We have seen, in the case of the inferior planets, Mercury and Venus, that our being out of the center makes them appear to run backwards and forwards across the sun, although they are all the while moving steadily on in one direction; and we know that our own motion along with the earth on its axis, every day, makes the heavens appear to move in the opposite direction. Hence, we see how very different may be the actual motions of the planets from what they appear to be. As we have said, they are actually very simple, moving steadily round the sun, all in one direction; but their apparent motions are exceedingly irregular. They sometimes move faster and sometimes slower —backwards and forwards—and at times appear to stand still for a considerable period.

276. If we have ever passed swiftly by a small vessel, sailing in the same direction with ourselves, but much slower, we may have seen the vessel appear to be moving backward, stern foremost. For a similar reason, the superior planets sometimes seem to move backwards, merely because the earth has a swifter

275. What makes the planetary motions appear very different from what they really are? Are the real motions more or less simple than the apparent?

motion, and sails rapidly by them. Then
seem to stand still, because they are abo
when our motion has ceased to carry them
backwards any further, and they are recov
direct motion. They appear also to stand
they are moving directly towards us or f
Mercury or Venus does when near its gre
gation. (See Fig. 109, page 242.) A di
assist us in obtaining a clear idea of the wa
these appearances are produced.

Fig. 115.



277. Let the inner circle, A B C, repr
earth's orbit, and the outer circle the orbit

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276. Appearance of a vessel when we pass rapidly by it
the superior planets appear to move backwards, and to s

(or any other superior planet,) and N R a portion of the concave sphere of the heavens. To make the case simple, we will suppose Mars to be stationary at M, in opposition; for, although he is actually moving eastward all the while, yet, since the earth is moving the same way more rapidly, their relative situations will be the same, if we suppose Mars to stand still and the earth to move on with the excess of its motion above that of the planet. As the earth moves from A to B, Mars appears to move backward from P to N; for the planet will always appear in the heavens in the direction of the straight line, as B M, drawn from the spectator to the body. When the earth is at B, Mars appears stationary, because the earth is moving directly from him and the line B M N does not change its direction. But while the earth moves on to C, D, E, F, the planet resumes a direct motion eastward through O, P, Q, R. Here it again stands still, while the earth is moving directly towards it, and then goes backward again. When the planet is in opposition, the earth being at A, its motion appears more rapid than in other situations, because then it is nearest to us. In the superior conjunction, when the earth is at D, the motion of Mars is comparatively slow.

278. There are three great Laws that regulate the motions of all bodies belonging to the Solar System, called KEPLER'S LAWS, from the name of the great astronomer who discovered them. The first is, that *the orbits of the earth and all the planets are ellipses, having the sun in one of the foci of the ellipse.* Figure 116 represents such an ellipse, differing but little from a circle, but still having the diameter, A B, called the *major axis* of the orbit, perceptibly longer than C D. The

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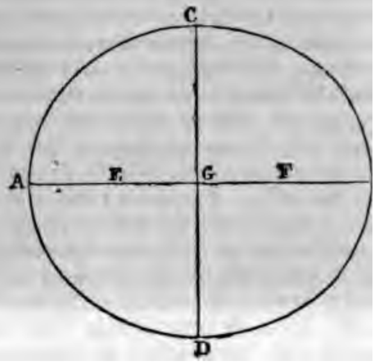
277. Illustrate the motion of Mars from Fig. 11– ... tion most rapid? When slow?

278. Kepler's Laws. Repeat the ... the *major axis—foci—perihelion—*

two points, E and F, (being the points from
a certain process, the figure is described,) a

Fig. 116.



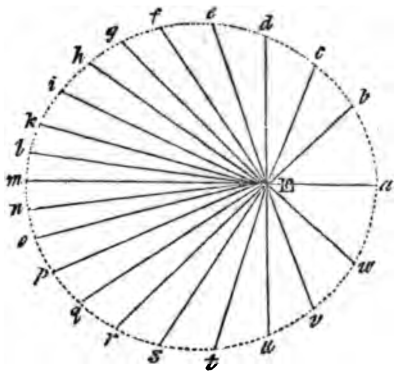
the two *foci*, and each of them, a *focus*, of th
Suppose the sun at F, then B will be the *pe*
nearest distance of a planet to the sun, and
aphelion, or farthest distance.

279. A line drawn from the sun to a plane
the ***radius vector***, as E *a* or E *b*, (Fig. 117 ;
second of Kepler's Laws is, that while a plane
round the sun, ***the radius vector passes over eq***
in equal times. The meaning of this is, t
imaginary line, as a cord, were extended fro
to any planet, this cord would sweep over jus
space one day as another. When the plane
perihelion, the cord would, indeed, move fa
towards the aphelion ; but it would also be

279. What is the radius vector? Repeat the second
plain its meaning.

he greater breadth of the space, E *a b*, would it just equal to the narrower but longer space,

Fig. 117.



. This law has been of incalculable service in all igher investigations of astronomy.

0. The third of Kepler's Laws is, that *the squares periodic times of different planets, are proportioned cubes of the major axes of their orbits.* Now the dic time of a planet, or the time it takes to go l the sun, from any star back to the same star , can be seen by watching it, as has often been during the whole of its revolution. We also the length of the major axis of the earth's orbit, se it is just twice the average or mean distance earth from the sun. These things being known, n find the distance of any of the planets from the y a simple statement in the rule of three. For ple, let it be required to find the major axis of

Repeat the third law. What is meant by the periodic time of a ? How may be the periodic time

Jupiter's orbit, or the mean distance of Jupiter from the sun, which is half the length of that axis. Then, since the earth's periodic time is one year, and Jupiter's twelve years, (putting E for the earth's distance from the sun, and J for Jupiter's,) we say,

$$1^2 : 12^2 :: E^3 : J^3.$$

Now the three first terms in this proportion are known, and hence we can find the fourth, which is the cube of Jupiter's distance from the sun; and, on extracting the cube root, we find the distance itself. We see, therefore, that the planetary system is laid off by an exact mathematical scale.

281. The three foregoing laws are so many great facts, fully entitled to be called *general principles*, because they are applicable not only to this or that planet, but to all the planets alike, and even to comets, and every other kind of body that may chance to be discovered in the solar system. They are the rules according to which all the motions of the system are performed. But there is a still higher inquiry, respecting the *causes* of the planetary motions, which aims at ascertaining not in *what manner* the planets move, but *why* they move at all, and by what *forces* their motions are produced and sustained. Sir Isaac Newton first discovered the great principle upon which all the motions of the heavenly bodies depend, that of *Universal Gravitation*. In its simplest expression it is nearly this: *all matter attracts all other matter*. But a more precise expression of the law of gravitation is as follows: *Every body in the universe, whether great or small, attracts every other body, with a force which*

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major axis of the earth's orbit? How to find the major axis o Jupiter's orbit?

281. Why are these laws called general principles? What higher inquiry is there? Who first discovered the grand law of the celestial motions? What is it called? Its simplest expression? Its more precise expression?

is proportioned to the quantity of matter directly, and to the square of the distance inversely.

282. This is the most comprehensive and important of all the laws of nature, and ought therefore to be clearly understood in its several parts. *First*, it asserts that *all matter* in the universe is subject to it. In this respect it differs from *Gravity*, which respects only the attraction exerted by the earth, and all bodies within the sphere of its influence. But Universal Gravitation embraces the whole solar system—sun, moon, planets, comets, and any other form of matter within the system. Nor does it stop here; it extends likewise to the stars, and comprehends the infinitude of worlds that lie in boundless space. *Secondly*, the law asserts that the attraction of gravitation is in proportion to the *quantity of matter*. Every body gives and receives of this mysterious influence an amount exactly proportioned to its weight; and hence all bodies exert an equal force on each other. The sun attracts the earth and the earth the sun, and one just as much as the other; for if the sun, in consequence of its having 354,000 times as much matter as the earth, exerts upon it 354,000 times as much force as it would do if it had the same weight with the earth, it also receives from the earth so much more in consequence of its greater weight. Were the sun divided into 354,000 bodies, each as heavy as the earth, every one would receive an equal share of the earth's attraction, and of course the whole would receive in the same degree as they imparted. *Thirdly*, the law asserts that, at different distances, the force of gravitation is *inversely as the square of the distance.* If a body is *twice* as far off, it attracts and is attracted

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282. What is said of the importance of this law? What does it assert *first*—what *secondly*? How much does every body give and receive of this influence? Example in the earth and sun. What does the law assert *thirdly*? How much less does a body attract another when twice as far off, or ten times as far?

four tir ess; if *ten* times as far, one hundred times l if a *hundred* times as far, ten thousand times l

283. great principle, which has led to a knowledge o causes of the celestial motions, and given us an i t into the machinery of the Universe, was discov by Sir Isaac Newton, who is generally ackno ed to have had the most profound mind of any pl pher that has ever lived. He was born in a coun wn in England in the year 1642. He was a farm having died before he was b ed him for a farmer; but his ble passion for study, and th us he displayed in his boyhoo unate determination to educat r.

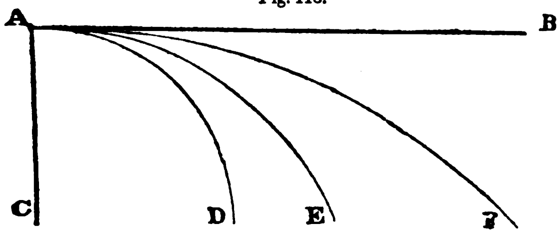
284. principle of Gravitation is applie xplain the revolutions of the heavenly bodies. If I throw a stone horizontally, the attraction of the earth will continually draw it downwards, out of the line of direction in which it was thrown, and make it descend to the earth in a curve. The particular form of the curve will depend on the velocity with which it is thrown. It will always *begin* to move in the line of direction in which it is projected; but it will soon be turned from that line towards the earth. It will, however, continue nearer to the line of projection, in proportion as the velocity of projection is greater. Let A C (Fig. 118) be perpendicular to the horizon, and A B parallel to it, and let a stone be thrown from A in the direction of A B. It will, in every case, commence its motion in the line A B, which will therefore be a tangent to the curve it de-

283. What is said of Sir Isaac Newton?

284. How is the principle of universal gravitation applied to the explanation of the celestial motions? How will a stone move when thrown horizontally? Explain Fig. 118.

scribes; but, if it be thrown with a small velocity, it will soon depart from the tangent, describing the curve

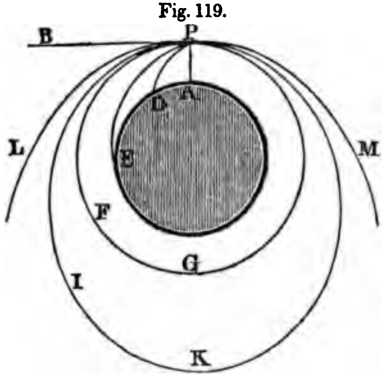
Fig. 118.



A D; with a greater velocity, it will describe a curve nearer the tangent, at A E; and with a still greater velocity, it will describe the curve A F.

285. As an example of a body revolving in an orbit under the influence of two forces, suppose a body

Fig. 119.

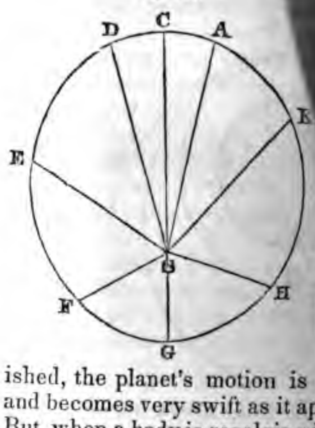


placed at any point, P, (Fig. 119,) above the surface of the earth, and let P A be the direction of the earth's

285. *Explain the motions of a body from Fig. 119.*

center, or a line perp
body were allowed t
impulse, it would desc
of P A with an acceler
at the moment of its
blow in the direction,
in the time the body
under the influence of
along the curve P D.
to it in the direction P
curve, P E; or, finally,
strong, it would circul
scribing the circle P F
tion still greater, it woul
and if the velocity were
the figure would become
which never returns into

Fig. 120.



b
in
pr
the
is
the
ished, the planet's motion is cont
and becomes very swift as it approa
But, when a body is revolving in a c

286. Explain the motions of a p

velocity causes a rapid increase in the *centrifugal force*, and makes it endeavor with more and more force to fly off in the direction of a tangent to its orbit. Hence, the increase of velocity as it approaches the sun, will not carry it into the sun, but the more rapid increase of the centrifugal force will keep it off, and carry it by, and finally make it describe the remaining portion of the curve, back to the place where it set out. After it passes the perihelion, at G, the sun's attraction constantly operates to hold it back, and as it proceeds through H and K to A and C, it is like a ball rolled up hill, until finally its motion becomes so slow, that the centrifugal force yields to the force of attraction, and it turns about to renew the same circuit.

287. Since the nature of the curve which any planet describes depends on the proportion between the two forces, of projection and attraction, astronomers have inquired what proportion must have been observed when the planets were first launched into space, in order that they should have revolved in the orbits they have; and it is found that the forces were so adjusted as to make the centrifugal and attractive forces nearly equal, that of projection being a little greater. Had they been exactly equal, the curve would have been a circle; and had the force of projection been much greater than it was, the ellipses would have been much longer, and the whole system much more irregular. The planets also revolve on their axes at the same time that they revolve around the sun; and astronomers have inquired what must have been the nature of the impulses originally given, in order to have produced these two motions such as they are. If we strike a ball in the exact line of the center of gravity, it will move forwards without turning on its axis; but if we

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287. How were the forces of projection and attraction adjusted to each other, wh[illegible] were first launched into space? How

strike it out of that direction we can make
ward and turn on its axis at the same tim
culated that the earth must have received
which gave to her her two motions, at a d
the center equal to the $\frac{1}{165}$th part of the e
Such an impulse would suffice to give the
in question; but it would be presumptuo
take to assign the exact mode by which t
first impressed upon the planetary system
ous movements; and all such expressions
ing these bodies into space," or "impelli
certain directions, must be regarded as
of speech.

288. Beside explaining the revolutions
venly bodies, the principle of universal gr
counts for all their *irregularities*. Since
in the solar system attracts every other, e
to be drawn out of its customary path,
bodies tend mutually to disturb each othe
Most of them are so far apart as to feel
influence but little; but in other cases, wh
bodies come far within each other's sphe
tion, the mutual disturbance of their moti
great. The moon, especially, has its m
tinually disturbed by the attractive force
When the sun acts equally on the earth an
as it does when the two bodies are at the
tance from him, he does not disturb their n
tions; as the passengers on board a steam
tain the same position with respect to
whether the boat is going with or against
But, at new moon, the moon being nearer t

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must they have been impelled in order to have the two m
must the earth have been struck?

288. Beside the revolutions of the heavenly bodies,
does the principle of universal gravitation account? H
traction of different bodies tend to affect each other's mo
is said of the moon? When does the sun disturb the m

he earth is, is more attracted than the earth; and at ull moon, the earth being nearer the sun than the moon s, is more attracted than the moon. Hence, in both ases, the sun tends to separate the two bodies. At other times, as when the moon is in quadrature, the influence of the sun tends to bring the bodies nearer together. Sometimes it causes the moon to move faster, and sometimes slower; so that owing to these various causes, the moon's motions are continually disturbed, which subjects her to so many irregularities, that it has required vast labor and research to ascertain the exact amount of each, and so to apply it as to assign the precise place of the moon in the heavens at any given time.

289. Among all the irregularities to which the heavenly bodies are subject, there is not one which the principle of universal gravitation does not account for, and even render necessary; so that if it had never been actually observed, a just consideration of the consequences of the operation of this principle, would authorize us to say that it must take place. Indeed, many of the known irregularities were first discovered by the aid of the doctrine of gravitation, and afterwards verified by actual observation. Such a tendency of all the heavenly bodies to disturb each other's motions, might seem to threaten the safety of the whole system, and throw the whole into final disorder and ruin; but astronomers have shown, by the aid of this same principle, that all possible irregularities which can occur among the planets, have a narrow, definite limit,—increasing first on one side, then on the other, and thus

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of the moon and earth? When does the sun attract the moon more than the earth? When the earth more than the moon? What various disturbances does it produce on the moon's motions?

289. Does the principle of universal gravitation account for the irregularities of the celestial motions? How were many of them first discovered? Will these irregularities produce disorder and ruin? What has been shown respecting their limit?

vibrating forever about a mean value, v the stability of the universe.

CHAPTER VII.

COMETS.

DESCRIPTION—MAGNITUDE AND BRIGHTNESS—PERI OF MATTER—MOTIONS—PREDICTION OF THEIR GERS.

290. Nothing in astronomy is more tru than the knowledge which astronomers h of the motions of comets, and the pow gained of predicting their return. Indee belonging to this class of bodies is so wo seem rather a tale of romance than a sim facts.

291. A comet, when perfectly forme three parts, the nucleus, the envelope, The *nucleus*, or body of the comet, is u guished by its forming a bright point in the head, conveying the idea of a solid, a dense portion of matter. Though it is small when compared with the other parts and is sometimes wanting altogether, yet ally is large enough to be measured by th telescope. The *envelope* (sometimes call from a Latin word signifying hair, in al hairy apperance,) is a thick, misty coveri rounds the head of the comet. Many con nucleus, but present only a foggy mass. I is a regular gradation of comets, from such posed merely of a gaseous or vapory medi

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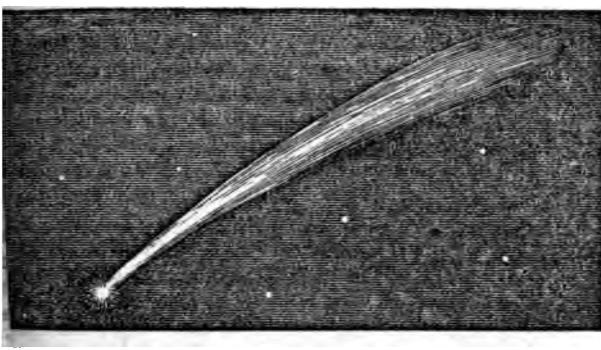
290. What is said of the knowledge astronomers comets?

291. Specify the several parts of a comet, and desc

which have a well defined nucleus. In some instances, astronomers have detected, with their telescopes, small stars through the densest part of the comet. The tail is regarded as an expansion or prolongation of the envelope, and presenting, as it sometimes does, a train of astonishing length, it confers on this class of bodies their peculiar celebrity. These several parts are exhibited in Fig. 121, which represents the appearance

Fig. 121.



of the celebrated comet of 1680, and which, in general size and shape, is not unlike that of 1843. The latter, however, was not so broad in proportion to its length, and its head (including the nucleus and coma) was far less conspicuous.

292. In *magnitude* and *brightness*, comets exhibit great diversity. History informs us of several comets so bright, as to be distinctly visible in the day time, even at noon, and in the brightest sunshine. Such was the comet seen at Rome a little before the assas-

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the nucleus—the envelope—the tail. How did the comet of 1680 compare with that of 1843?

292. What is said of the magnitude and brightness of comets? Of the *comet seen at Rome*? Of that of 1680? Of 1811? How small

sination of Julius Cæsar; and, in a superstitious age, very naturally considered as the precursor of that event. The comet of 1680 covered an arc of the heavens of ninety-seven degrees, sufficient to reach from the setting sun to the zenith, and its length was estimated at 123,000,000 miles. The comet of 1811, had a nucleus only 428 miles in diameter, but a tail 132,000,000 miles long; and had it been coiled around the earth like a serpent, it would have reached round more than 5000 times. Other comets are exceedingly small, the nucleus being in one case estimated at only 25 miles; and some which are destitute of any perceptible nucleus, appear to the largest telescopes, even when nearest to us, only as a small speck of fog. The majority of comets can be seen only by the aid of the telescope. Indeed, the same comet has different appearances at its different returns. Halley's comet, in 1305, was described by the historians of that age, as the comet of "horrific magnitude;" yet, in 1835, when it re-appeared, the greatest length of its tail was only about twelve degrees, whereas that of the comet of 1843 was about forty degrees.

293. The *periods* of comets, in their revolutions around the sun, are equally various. Encke's comet, which has the shortest known period, completes its revolution in $3\frac{1}{3}$ years; while that of 1811 is estimated to have a period of 3,383 years. The distances to which different comets recede from the sun, are equally various. While Encke's comet performs its entire revolution within the orbit of Jupiter, Halley's comet recedes from the sun to twice the distance of Uranus, or 3600,000,000 miles. Some comets, indeed, are thought to go a much greater distance from the sun

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are some comets? How does the same comet appear at its different returns?

293. What is said of the periods of the comets? Of Encke's comet? Of that of 1811? What of the distances to which they recede from the sun?

than this; while some are supposed to pass into curves, which do not, like the ellipse, return into themselves; and, in this case, they never come back to the sun.

294. Comets shine *by reflecting the light of the sun.* In one or two cases, they have been thought to exhibit distinct *phases*, like the moon, and experiments made on the light itself, indicate that it is reflected and not direct light. The tails of comets extend *in a direct line from the sun*, following the body as it approaches that luminary, and preceding the body as it recedes from it.

295. The *quantity of matter* in comets is exceedingly small. The tails consist of matter so light, that the smallest stars are visible through them. They can only be regarded as masses of thin vapor, susceptible of being penetrated through their whole substance by the sunbeams, and reflecting them alike from their interior parts and from their surfaces. "The highest clouds that float in our atmosphere," (says a great astronomer, Sir John Herschel,) "must be looked upon as dense and massive bodies compared with the filmy and all but spiritual texture of a comet." The small quantity of matter in comets is proved by the fact, that they have at times passed very near to some of the planets, without disturbing their motions in any appreciable degree. As the force of gravity is always proportioned to the quantity of matter, were the density of these bodies at all comparable to their size, on coming near one of the planets, they would raise enormous tides, and perhaps even draw the planet itself out of its orbit. But the comet of 1770, in its way to the sun, got entangled among the satellites of Jupiter, and remained near them four months; yet it did not

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294. By what light do comets shine? Do they ever exhibit phases? What is the direction of their tails?

295. Quantity of matter in comets? Extreme thinness? What proofs are stated to show their small quantity of matter? What is said

perceptibly change their motions. The same comet also came very near to the earth; so that, had its quantity of matter been equal to that of the earth, it would, by its attraction, have caused the earth to have revolved in an orbit so much larger than at present, as to have increased the length of the year two hours and forty-seven minutes. Yet it produced no sensible effect on the length of the year. It may, indeed, be asked, what proof we have that comets have *any* matter, and are not mere reflexions of light? The answer is, that although they are not able, by their own force of attraction, to disturb the motions of the planets, yet they are themselves exceedingly disturbed by the action of the planets, and in exact conformity with the laws of universal gravitation. A delicate compass may be greatly agitated by the vicinity of a mass of iron, while the iron is not sensibly affected by the attraction of the needle.

296. The *motions* of comets are the most wonderful of all their phenomena. When they first come into view, at a great distance from the sun, as is sometimes the case, they make very slow approaches from day to day, and even, in some cases, advance but little from week to week. When, however, they come near to the sun, their velocity increases with prodigious rapidity, sometimes exceeding a million of miles an hour; they wheel around the sun like lightning; and recede again with a velocity which diminishes at the same rate as it before increased. We have seen that the planets move in orbits which are nearly circular, and that therefore they always keep at nearly the same distance from the sun. Not so with comets. Their perihelion distance is sometimes so small that they almost

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of the comet of 1770? What proof have we that they contain any matter?

296. What is said of the motions of comets? What is the shape of their orbits? Of their distance from the sun at the perihelion and at

graze his surface, while their aphelion lies far beyond the utmost bounds of the planetary system, towards the region of the stars. This was the case with the comet of 1680, and the same is probably true of the wonderful comet of 1843. But irregular as are their motions, they are all performed in exact obedience to the great law of universal gravitation. The radius vector always passes over equal spaces in equal times; the greater length of the triangular space described at the aphelion, where the motion is so slow, being compensated by the greater breadth of the triangular space swept over at the perihelion, where the motion is so swift.

297. The appearances of the same comet at different periods of its return are so various, that we can never pronounce a given comet to be the same with one that has appeared before, from any peculiarities in its form, size, or color, since in all these respects it is very different at different returns; but it is judged to be the same if its *path* through the heavens, as traced among the stars, is the same. If, on comparing two comets that have appeared at different times, they both moved in orbits equally inclined to the ecliptic; if they crossed the ecliptic in the same place among the stars; if they came nearest the sun, or passed their perihelion, in the same part of the heavens; if their distance from the sun at that time was the same; and, finally, if they both moved in the same direction with regard to the signs, that is, both east, or both west; then we should pronounce them to be one and the same comet. But if they disagreed in more or less of these particulars, we should say that they were not the same but different bodies.

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their aphelion? Are the motions of a comet subject to the laws of gravitation?

297. How do we determine that a comet is the same with one that has appeared before? Enumerate the several particulars in which the two must agree?

298. Having established the identity of a comet with one that appeared at some previous period, the interval between the two periods would either be the time of its revolution, or some multiple or aliquot part of that time. Should we, for example, find a present comet to be identical with one that appeared 150 years ago, its period might be either 150 or 75 years, since possibly it might have returned to the sun twice in 150 years, although its intermediate return, at the end of 75 years, was either not observed or not recorded. Hence the method of *predicting* the return of a comet which has once appeared requires, first, that we ascertain with all possible accuracy the particulars enumerated in article 297, which are called the *elements* of the comet, and then compare these elements with those of other comets as recorded in works on this subject. The elements of about 130 comets have been found and registered in astronomical works, to serve for future comparison, but three only have their periodic times certainly determined. These are Halley's, Biela's, and Encke's comets; the first of which has a period of 75 or 76 years; the second, of $6\frac{3}{4}$ years; the third, of $3\frac{1}{3}$ years.

299. Halley's comet is the most interesting of these, and perhaps, on all accounts, the most interesting member of the solar system. It was the first whose return was predicted with success. Having appeared in 1682, Dr. Halley, a great English astronomer, then living, ascertained that its elements were the same with one that had appeared several times before, at intervals corresponding to about seventy-six years, and hence pronounced this to be its period, and predicted

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298. When the identity with a previous comet is established, how do we learn the time of its revolution? What is the method of predicting their return? Of how many comets have the elements been determined? How many have their periods certainly ascertained?

299. What is said of Halley's comet? What prevented Halley's fixing the exact moment of its return? What is said about weighing

that ...
part of ...
It ...
March ...
moment ...
respect ...
motions ...
have ...
come ...
greatly ...
attraction ...
amount ...
quantity ...
is, they ...
imperfectly ...
greatest ...
Saturn. ...
merchandize ...
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300. The ...
was truly ...
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wholly ...
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be followed ...
3600,000. ...
precise time ...
the amount of ...
tions, arising ...
ets, must be ...
these forces ...

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the planets? ...
fulfilled in 1835?

300. What is said ...

distance, the calculation was to be made for every degree of the orbit, separately, through 360 degrees, for a period of seventy-six years. Guided, however, by such an unerring principle as universal gravitation, astronomers felt no doubt that the comet would be true to its appointed time, and they therefore told us, months beforehand, the time and manner of its first approach, and its subsequent progress. They told us that early in August, 1835, the comet would appear to the telescope as a dim speck of fog, at a certain hour of the night, in the northeast, not far from the seven stars; that it would slowly approach us, growing brighter and larger, until in about a month, it would become visible to the naked eye; that, on the night of the seventh of October, it would approach the constellation of the Great Bear, and move along the northern sky through the seven bright stars of that constellation called the Dipper; that it would pass the sun about the middle of November, and re-appear again on the other side of the sun about the end of December. All these predictions were verified, with a degree of exactness that constitutes this one of the highest achievements of science.

301. Since comets which approach very near the sun, like the comets of 1680 and 1843, cross the orbits of all the planets, in going to the sun and returning, the possibility that one of them may strike the earth has often been suggested, and at times created great alarm. It may quiet our apprehensions on this subject to reflect on the vast extent of the planetary spaces, in which these bodies are not crowded together as we see them erroneously represented in orreries and diagrams, but are sparsely scattered at immense distances from each other, resembling insects flying in the open

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Describe the difficulties attending it. What did astonomers tell us beforehand? How were these predictions fulfilled?

301. What is said of the danger that a comet will strike the earth?

heaven. Such a meeting with the earth is a very improbable event; and were it to happen, so extremely light is the matter of comets, that it would probably be stopped by the atmosphere; and if the matter is combustible, as we have some reason to think, it would probably be consumed without reaching the earth. And, finally, notwithstanding all the evils of which comets, in different ages of the world, have been considered as the harbingers, we have no reason to think that they ever did or ever will do the least injury to mankind.

CHAPTER VIII.

FIXED STARS.

NUMBER, CLASSIFICATION, AND DISTANCE OF THE STARS—DIFFERENT GROUPS AND VARIETIES—NATURE OF THE STARS, AND THE SYSTEM OF THE WORLD.

302. Vast as are the dimensions of the Solar System, to which our attention has hitherto been confined, it is but one among myriads of systems that compose the Universe. Every star is a world like this. The *fixed stars* are so called, because, to common observation, they always maintain the same situations with respect to each other. In order to obtain as clear and distinct ideas of them as we can, we will consider, under different heads, the number, classification, and distances of the stars—their various orders—their nature—and their arrangement in one grand system.

SEC. 1. *Of the Number, Classification, and Distances of the Stars.*

What would happen if it should? Have comets ever been known to do any injury?

302. Why are the fixed stars so called? Under what different heads *are the fixed stars* considered?

303. en we look at the firmament on a clear
winter ht, the *number* of stars visible even to the
naked seems immense. But when we actually
begin t nt them, we are surprised to find the num-
ber so ll. In some parts of the heavens, half
a doze s will occupy a large tract of the sky,
althou other parts, they are more thickly crowded
togeth Hipparchus of Rhodes, in ancient times,
first co the stars, and stated their number at 1022.
If we on the equator, where we can see both the
northe ere, and carefully enu-
merate view at all seasons of
the yea amount to 3000. The
telesco ew hosts of stars invis-
ible to mber increasing with
every i instrument; so that we
may p stars that are actually
distributed through the fields of space, to be literally endless. Single groups of half a dozen stars, as seen by the naked eye, often appear to a powerful telescope in the midst of hundreds of others of feebler light. Astronomers have actually registered the positions of no less than 50,000; and the whole number visible in the largest telescopes amounts to many millions.

304. The stars are *classed* by their apparent magnitudes. The whole number of magnitudes recorded is sixteen, of which the first six only are visible to the naked eye; the rest are *telescopic* stars. These magnitudes are not determined by any very definite scale, but are merely ranked according to their relative degrees of brightness, and this is left in a great measure to the judgment of the eye alone. The brightest stars,

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303. Apparent number of the stars on a general view. Result when we count them. Who first made a catalogue of the stars? How many were included? What is the greatest number visible to the naked eye? Numbers visible in the telescope? Whole number?

304. How are the stars classed? How many magnitudes? How many of them are visible to the naked eye? What are the rest called?

to the number of fifteen or twenty, are considered as stars of the first magnitude; the fifty or sixty next brightest, of the second magnitude; the next two hundred, of the third magnitude; and thus the number of each class increases rapidly, as we descend the scale, so that no less than fifteen or twenty thousand are included within the first seven magnitudes.

305. The stars have been grouped in *constellations* from the most remote antiquity. A few, as Orion, Bootes, and Ursa Major, (the Great Bear,) are mentioned in the most ancient writings, under the same names as they have at present. The names of the constellations are sometimes founded on a supposed resemblance to the objects to which those names belong; as the Swan and the Scorpion were evidently so denominated from their likeness to these animals. But, in most cases, it is impossible for us to find any reason for designating a constellation by the figure of the animal or hero which is employed to represent it. These representations were probably once connected with the fables of heathen mythology. The same figures, absurd as they appear, are still retained for the convenience of reference; since it is easy to find any particular star, by specifying the part of the figure to which it belongs; as when we say a star is in the *neck* of Taurus, in the *knee* of Hercules, or in the *tail* of the Great Bear. This method furnishes a general clue to their position; but the stars belonging to any individual constellation, are distinguished according to their apparent magnitudes, as follows: First, by the Greek letters, Alpha, Beta, Gamma, &c. Thus, *Alpha*, of Orion, denotes the largest star in that constellation;

How many stars of the first magnitude? How many of the second? Of the third? How many within the first seven?

305. What is said of the antiquity of the constellations? Origin of their names? Why are the ancient figures retained? How are the individual stars of a constellation denoted?

Beta, of Andromeda, the second star in that; and *Gamma*, of the Lion, the third brightest star in the Lion. When the number of the Greek letters is insufficient, recourse is had to the letters of the Roman alphabet, a, b, c, &c.; and in all cases where these are exhausted, the final resort is to numbers. This will evidently at length become necessary, since the largest constellations contain many hundreds or even thousands of stars.

306. When we look at the firmament on a clear Autumnal or Winter evening, it appears so thickly set with stars, that one would perhaps imagine, that the task of learning even the brightest of them would be almost hopeless. So far is this from the truth, that it is a very easy task to become acquainted with the names and positions of the stars of the first magnitude, and of the leading constellations. It is but, at first, to obtain the assistance of an instructor, or some friend who is familiar with the stars, just to point out a few of the most conspicuous constellations. A few of the largest stars in it will serve to distinguish a constellation, and enable us to recognize it. These we may learn first, and afterwards fill up the group by finding its smaller members. Thus we may at first content ourselves with learning to recognize the Great Bear, by the seven bright stars called the *Dipper;* and we might afterwards return to this constellation, and learn to trace out the head, the feet, and other parts of the animal. Having learned to recognize the most noted of the constellations, so as to know them the instant we see them any where in the sky, we may then learn the names and positions of a few single stars of special celebrity, as *Sirius*, (the Dog-star,) the brightest of all the fixed stars, situated in the constellation Canis Ma-

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306. Is it a difficult task to learn the constellations, and the names of the largest stars ? What directions are given ?

jor, (the Greater Dog;) *Aldebaran*, in Taurus; *Arcturus*, in Bootes; *Antares*, in the Scorpion; *Capella*, in the Waggoner.

307. It is a pleasant evening recreation for a small company of young astronomers to go out together, and learn one or two constellations every favorable evening, until the whole are mastered. A map of the stars, placed where the company can easily resort to it, will, by a little practice, enable them to find the relative situations of the stars, with as much ease as they find those of places on the map of any country. A celestial globe, when it can be procured, is better still; for it may be so *rectified* as to represent the exact appearance of the heavens on any particular evening. It will be advisable to learn first the constellations of the zodiac, which have the same names as the signs of the zodiac enumerated in Article 203, (Aries, Taurus, Gemini, &c.;) although any order may be pursued that suits the season of the year. The most brilliant constellations are in the evening sky in the Winter.*

308. Great difficulties have attended the attempt to measure the *distances* of the fixed stars. We must here call to mind the manner in which the distances of nearer bodies, as the moon and the sun, are ascertained, by means of parallax. The moon, for example, is at the same moment projected on different points of the sky, by spectators viewing her at places on the earth at a distance from each other. (See Art. 218.) By means of this apparent change of place in the moon, when viewed from different places, astron-

* For more particular directions for studying the constellations, including a description of the most important of them, the author begs leave to refer to his larger books, as the "School Astronomy," and "Letters on Astronomy."

307. What is proposed as an evening's recreation? What use is to be made of a celestial map or globe? With what constellations is it advisable to commence?

308. What is said of the attempt to measure the distances of the fix-

omers, as already explained, derive her hori
allax, and from that her distance from th
the earth. The stars, however, are so fa
they have no horizontal parallax, but app
in the same direction, whether viewed fro
of the earth or another. They have not, in
very recently, appeared to have any *annua*
by which is meant, that they do not shift tl
in the least in consequence of our viewi
different extremities of the earth's orbit,—
of 190,000,000 of miles. The earth, in
revolution around the sun, must be so muc
certain stars that lie on one side of her orbi
is to the same stars when on the opposite
orbit; and yet even this immense change i
of the spectator, makes no apparent cha
position of the stars of the first magnitu
from their being so conspicuous, were natu
red to be nearest to us. Although this res
tell us how far off the stars actually are, y
us that they cannot be within a distance
millions of millions of miles; for were t
that distance, the nicest observations woul
them *some* annual parallax. If these conc
drawn with respect to the largest of the
which we suppose to be vastly nearer to
those of the smallest magnitude, the idea
swells upon us when we attempt to estim
moteness of the latter. Of some stars it i
thousands of years would be required for tl
travel down to us.

309. By some recent observations, how
supposed that the long sought for parallax
fixed stars has been discovered. In the

ed stars? Have the stars in general any horizontal par
is meant by saying that the stars have no annual paral
what distance must the great body of the stars be?

Professor Bessel, of Koningsberg, (Prussia,) announced the discovery of a parallax in one of the stars of the constellation Swan, (61 *Cygni*,) amounting to about *one third of a second.* This seems, indeed, so small an angle, that we might have reason to suspect the reality of the determination; but the most competent judges, who have thoroughly examined the process by which the discovery was made, give their assent to it. What, then, do astronomers understand when they say, that a parallax has been discovered in one of the fixed stars, amounting to one-third of a second? They mean that the star in question apparently shifts its place in the heavens to that amount, when viewed at opposite extremities of the earth's orbit; namely, at points in space distant from each other 190,000,000 of miles. Let us reflect how small an arc of the heavens is one-third of a second! The angular breadth of the sun is but small, yet this is towards six thousand times as great as the discovered parallax. On calculating the *distance* of the star from us, by this means, it is found to be six hundred and fifty-seven thousand seven hundred times ninety-five millions of miles,—a distance which it would take light more than ten years to traverse.

Sec. 2. *Of Groups and Varieties of Stars.*

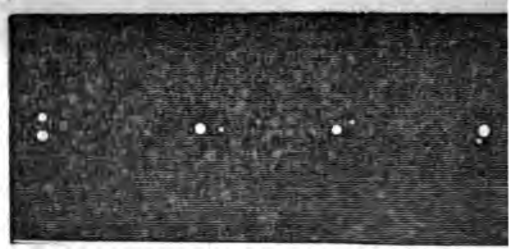
310. Under this head, we may consider Double, Temporary, and Variable Stars; Clusters and Nebulæ. *Double Stars* are those which appear single to the naked eye, but are resolved into two by the telescope; or, if not visible to the naked eye, they are such as,

309. Give an account of the discovery of the parallax of 61 Cygni? How much is it? What do astronomers understand by this? How much less angular breadth is one third of a second than the breadth of the sun? What distance does this imply?

310. Enumerate the different groups and varieties of the stars.

when seen in the telescope, are so close togethe1 to be regarded as objects of this class. Sometin three or more stars are found in this near connex constituting triple or multiple stars. Castor, for ample, (one of the two bright stars in the constella Gemini,) when seen by the naked eye, appears : single star; but in a telescope, even of moderate p er, it is resolved into two. These are nearly of e size; but, more commonly, one is exceedingly s in comparison with the other, resembling a sate near its primary, although in distance, in light, an other characteristics, each has all the attributes (star, and the combination, therefore, cannot be th

Fig. 122.



a star with a planetary satellite. The diagram sh four double stars, as they appear in large telescop

311. A circumstance which has given great inte to the double stars is, the recent discovery that s of them *revolve around each other*. Their time revolution are very different, varying in the cas those already ascertained, from 43 to 1000 year: more. The revolutions of these stars have reve to us this most interesting fact, that *the law of g*

What are double stars? Give an example in Castor. Why ma the smaller star be a planetary satellite?

tation extends to the fixed stars. Before these discoveries, we could not decide, except by a feeble analogy, that this law extended beyond the bounds of the solar system. Indeed, our belief rested more upon our idea of unity of design in the works of the Creator, than upon any certain proof; but the revolution of one star around another, in obedience to forces which are proved to be similar to those which govern the solar system, establishes the grand conclusion, that the law of gravitation is truly the law of the material universe.

312. *Temporary Stars* are new stars, which have appeared suddenly in the firmament, and after a sudden interval, as suddenly disappeared, and returned no more. It was the appearance of a new star of this kind, one hundred and twenty-five years before the Christian era, that prompted Hipparchus to draw up a catalogue of the stars, so that future astronomers might be able to decide the question, whether the starry heavens are unchangeable or not. Such, also, was the star which suddenly shone out in the year 389, in the constellation Eagle, as bright as Venus, and after remaining three weeks, disappeared entirely. In 1572, a new star suddenly appeared, as bright as Sirius, and continued to increase until it surpassed Jupiter when brightest, and was visible at mid-day. In a month, it began to diminish; and, in three weeks afterwards, it entirely disappeared. It is also found that stars are now missing, which were inserted in ancient catalogues, as then existing in the heavens.

313. *Variable Stars* are those which undergo a periodical change of brightness. One of these is the star *Mira*, in the whale. It appears once in eleven

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311. What has recently given great interest to the double stars? What inference is made respecting the law of gravitation?

312. What are temporary stars? What led Hipparchus to number the stars? What is said of the star of 389? Of 1572? What stars are now missing?

months, remains at its greatest brightness about a fortnight, being then equal to a star of the second magnitude. It then decreases about three months, until it becomes completely invisible, and remains so about five months, when it again becomes visible, and continues increasing during the remaining three months of its period. Another variable star in Perseus, goes through a great variety of changes in the course of three days. Others require many years to accomplish the period of their changes.

314. *Clusters* of stars will next claim our attention. In various parts of the sky, in a clear night, are seen large groups which, either by the naked eye, or by the aid of the smallest telescope, are perceived to consist of a great number of small stars. Such are the Pleiades, Coma Berenices, (Berenice's Hair,) and Præsepe, or the Beehive, in Cancer. The *Pleiades*, or Seven Stars, as they are called, in the neck of Taurus, is the most conspicuous cluster. With the naked eye, we do not distinguish more than six stars in this group; but the telescope exhibits fifty or sixty stars, crowded together, and apparently separated from the other parts of the starry heavens. *Berenices's Hair*, which may be seen in the summer sky in the west, a little westward of Arcturus, has fewer stars, but they are of a larger class than those which compose the Pleiades. The *Beehive*, or Nebula of Cancer, as it is called, is one of the finest objects of this kind for a small telescope. A common spy-glass, indeed, is sufficient to resolve it into separate stars. It is easily found, appearing to the naked eye somewhat hazy, like a comet, the stars being so near together that their light becomes blended. A reference to a celestial map or globe will show its exact position in the con-

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313. What are variable stars? Give an example in Mira, and in Perseus.

314. What is said of clusters of stars? Give examples. What is

stellation Cancer, and it will well repay those who can command a telescope of any size, for the trouble of looking it up. A similar cluster in the sword handle of Perseus, near the well known object, Cassiopea's Chair, in the northern sky, also presents a very beautiful appearance to the telescope.

315. *Nebulæ* are faint, misty appearances, which are dimly seen among the stars, resembling comets, or a speck of fog. A few are visible to the naked eye; one, especially, in the girdle of the constellation Andromeda, which has often been reported as a newly discovered comet. The greater part, however, are visible only to telescopes of greater or less power. They are usually resolved by the telescope into myriads of small stars; though, in some instances, no powers of the telescope have been found sufficient to resolve them. The Galaxy, or Milky Way, presents a continual succession of large nebulæ. The great English astronomer, Sir William Herschel, has given catalogues of 2,000 nebulæ, and has shown that nebulous matter is distributed through the immensity of space in quantities inconceivably great, and in separate parcels of all shapes and sizes, and of all degrees of brightness, between a mere milky veil and the condensed light of a fixed star. In fact, more distinct nebulæ have been hunted out by the aid of telescopes, than the whole number of stars visible to the naked eye in a clear winter's night. Their appearances are extremely diversified. In many of them we can easily distinguish the individual stars; in those apparently more remote, the interval between the stars diminishes, until it becomes quite imperceptible; and

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said of the Pleiades? What of Berenice's Hair? What of the Bee-hive? Of the cluster in Perseus?

315. What are Nebulæ? Are any visible to the naked eye? How do they appear by the telescope? What is said of the Galaxy or Milky Way? How many nebulæ did Herschel discover? Can we resolve

in their faintest aspect they dwindle to points so minute, as to be appropriately called *star dust*. Beyond this, no stars are distinctly visible, but only streaks or patches of milky light. In objects so distant as these assemblages of stars, any apparent interval between them must imply an immense distance; and were we to take our station in the midst of them, a firmament would expand itself over our heads like that of our evening sky, only a thousand times more rich and splendid; and were we to take our view from such a distant part of the universe, it is thought by astronomers that our own starry heavens would all melt together into the same soft and mysterious light, and be seen as a faint nebula on the utmost verge of creation.

316. Many of the nebulæ exhibit a tendency towards a globular form, and indicate a rapid condensation towards the center. These wonderful objects, however, are not confined to any particular form, but exhibit great varieties of figure. Sometimes they appear of an oval form; sometimes they are shaped like a fan; and the unresolvable kind often assume the most fantastic forms. But, since objects of this kind must be seen before they can be fully understood, it is hoped the learner will avail himself of any opportunity he may have to contemplate them through the telescope. Some of them are of astonishing dimensions. It is but little to say of many a nebula, that it would more than cover the whole solar system, embracing within it the immense orbit of Uranus.

SEC. 3. *Of the Nature of the Stars, and the System of the World.*

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them all into stars? If we were to take our position in the midst of a great nebula what should we see over our heads? How would our firmament appear?

316. What is said of the different forms of nebulæ? What of their dimensions?

317. We have seen that the stars are so distant, that not only would the earth dwindle to a point, and entirely vanish as seen from the nearest of them, but that the sun itself would appear only as a distant star, less brilliant than many of the stars appear to us. The diameter of the orbit of Uranus, which is about 3600,000,000 of miles, would, as seen from the nearest star, appear so small that the finest hair would more than cover it. The telescope itself, seems to lose all power when applied to measure the magnitudes of the stars; for although it may greatly increase their light, so as to make them dazzle the eye like the sun, yet it makes them no larger. They are still shining *points*. We may bring them, in effect, 6000 times nearer, and yet they are still too distant to appear otherwise than points. It would, therefore, seem fruitless to inquire into the nature of bodies so far from us, and which reveal themselves to us only as shining points in space. Still there are a few very satisfactory inferences that can be made out respecting them.

318. First, *the fixed stars are bodies greater than our earth.* Were the stars no larger than the earth, it would follow, on optical principles, that they could not be seen at such a distance as they are. Attempts have been made to estimate the comparative magnitudes of the brightest of the fixed stars, from the light which they afford. Knowing the rate at which the intensity of light decreases as the distance increases, we can find how far the sun must be removed from us, in order to appear no brighter than Sirius. The distance is found to be 140,000 times its present distance. But Sirius is more than 200,000 times as far off as the sun; hence it is inferred, that it must, upon the lowest estimate, give out twice as much light as the sun; or

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317. How would our sun appear from the nearest fixed star? How broad would the orbit of Uranus appear?

318. What is said of the size of the stars? Are the stars of various

to the discovery of a parallax, (see Art. 3
erally thought to have less than half th
matter in the sun, which accounts for the
so diminutive in size, while they are a
much nearer to us than the great body of

319. Secondly, *the fixed stars are Su*
ferred that they shine by their own light,
the planets, by reflected light, since re
would be too feeble to render them visil
distance. Moreover, it can be ascertain
ing certain tests to light itself, whether i
reflected light; and the light of the star
examined, proves to be direct. Since, th
are large bodies like the sun; since t
mensely farther off than the farthest pl
they shine by their own light; and, in
their appearance is, in all respects, the
sun would exhibit if removed to the region
the conclusion is unavoidable that the sta

the naked eye; nor as land marks to the navigator, for only a small portion of them are adapted to this purpose; nor, finally, to influence the earth by their attractions, since their distance renders such an effect entirely insensible. If they are suns, and if they exert no important agencies upon our world, but are bodies evidently adapted to the same purpose as our sun, then it is as rational to suppose that they were made to give light and heat, as that the eye was made for seeing and the ear for hearing.

320. We are thus irresistibly led to the conclusion, that each star is a world within itself,—a sun, attended, like our sun, by planets to which it dispenses light and heat, and whose motions it controls by its attraction. Moreover, since we see all things on earth contrived in reference to the sustenance, safety, and happiness of man,—the light for his eyes, the air for his lungs, the heat to warm him, and to perform his labors by its mechanical and chemical agencies; since we see the earth yielding her flowers and fruits for his support, and the waters flowing to quench his thirst, or to bear his ships, and all the animal tribes subjected to his dominion; and, finally, since we see the sun himself endued with such powers, and placed at just such a distance from him, as to secure his safety and minister in the highest possible degree to his happiness; we are left in no doubt that this world was made for the dwelling place of man. But, on looking upwards at the other planets, when we see other worlds resembling this in many respects, enlightened and regulated by the same sun, several of them much larger than the earth, furnishing a more ample space for intelligent beings, and fitted up with a greater number of moons

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made? Might it not have been to give light by night—to afford land marks to the navigator—or to exert a power of attraction on the earth?

320. To what conclusion are we thus led? For what end were the stars made?

tem of the World, or to see in what order bodies that compose the universe are arran thing is apparent to all who have studied nature,—that great *uniformity of plan* att department of the works of creation. A dr has the same constitution as the ocean ; a air, the same as the whole atmosphere. and the eggs of a particular species of bi same in all ages ; the anatomy of man is that the mechanism of one body is that o A similar uniformity pervades the mechan heavens. To begin with the bodies neare see the earth attended by a satellite, the revolves about her in exact obedience to universal gravitation. Since the discovery escope has enabled us to see into the me the other planets, we see that Jupiter, S Uranus, have each a more numerous retin still fashioned according to the same model dient to the same law. The recent disco titude of stars assembled together into one group; and, although we have not yet been able to detect a common system of motions of revolution among them, and on account of their immense distance, particularly of the nebulæ, perhaps we never shall be able, yet this very grouping indicates a mutual relation, and the symmetrical forms which many of them exhibit, prove an organization for some common end. Now such is the uniformity of the plan of creation, that where we have discovered what the plan is in the objects nearest to us, we may justly infer that it is the same in similar objects, however remote. Upon the strength of a sound analogy, therefore, we infer revolutions of the bodies composing the most distant nebulæ, similar to those which we see prevail among all nearer worlds.

322. This argument is strengthened and its truth rendered almost necessary, by the fact that without such motions of revolution, the various bodies of the universe would have a tendency to fall into disorder and ruin. By their mutual attractions, they would all tend directly towards each other, moving at first, indeed, with extreme slowness, but in the lapse of ages, with accelerated velocity, until they finally rushed together in the common center of gravity. We can conceive of no way in which such a consequence could be avoided, except that by which it is obviated in the systems which are subject to our observation, namely, by a projectile force impressed upon each body, which makes it constantly tend to move directly forward in a straight line, but which, when combined with the force of gravity existing mutually in all the bodies of the system, gives them harmonious revolutions around each other.

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indications of systematic arrangement do we see in the clusters and nebulæ?

322. What would happen to the various bodies in the universe, without such revolutions? How could such a consequence be avoided?

323. [illegible] see, then, in the subordinate members of the sola[illegible]stem, in the earth and its moon, in Jupiter, Saturn, [illegible] Uranus, with their moons, a *type* of the mecha[illegible] of the world, and we conclude, that the materia[illegible]verse is one great system; that the combination [illegible]anets with their satellites, constitutes the first or[illegible]st order of worlds; that, next to these, planets [illegible] linked to suns; that these are bound to other s[illegible]composing a still higher order in the scale of bein[illegible]nd, finally, that all the different systems of wor[illegible]r common center of gravity.

324. [illegible]regoing considerations present [illegible] the material universe, is almo[illegible] we can hardly avoid joining [illegible]at have been uttered, after t[illegible]he insignificant place which w[illegible]upy in the scale of being; nor cease to wonder, with Addison, that we are not lost among the infinitude of the works of God. It is cause of devout thankfulness, however, that omniscience and benevolence are at the helm of the universe; that the same hand which fashioned these innumerable worlds, and put them in motion, still directs them in their least as well as in their greatest phenomena; and that, if such a view as we have taken of the power of the Creator, fills us with awe and fear, the displays of care manifested in all his works for each of the lowest of his creatures, no less than for worlds and systems of worlds, should conspire with what we know of his works of Providence and Grace, to fill us with love and adoration.

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323. Describe the system of the world.

324. What is said of the grandeur of these views? What is special cause of thankfulness? How should the contemplation of the subject affect us?